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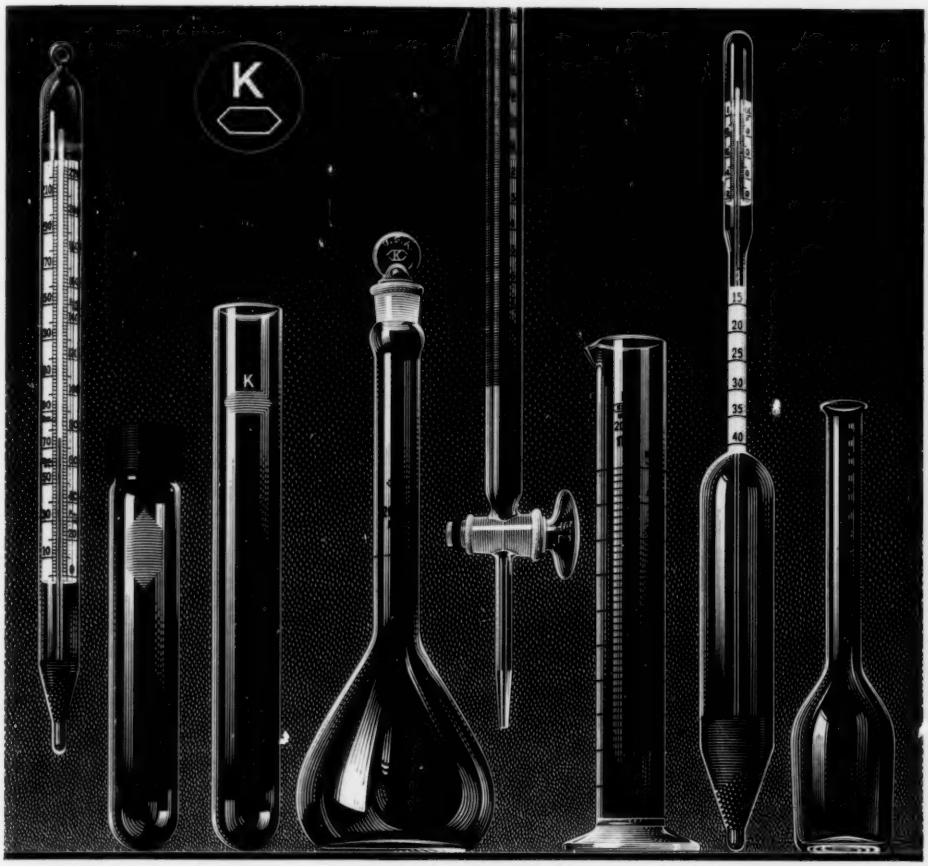

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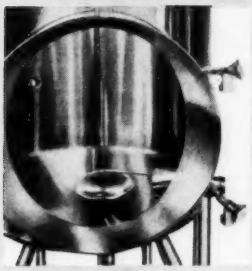

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INTERRELATIONSHIPS OF MICROORGANISMS IN CREAM. I. *STREPTOCOCCUS LACTIS, PSEUDOMONAS FRAGI,* AND *GEOTRICHUM CANDIDUM*[1]

L. G. HARMON[2] AND F. E. NELSON

Department of Dairy Industry, Iowa State College, Ames

Regulatory agencies and the dairy industry have been concerned about the amounts of lipolysis and proteolysis occurring in dairy products, particularly cream and butter. An investigation was performed to determine quantitatively the lipolytic, proteolytic, and other deterioration values resulting from the growth of common contaminating organisms in cream incubated at various temperatures.

In studying the lipase production of *Pseudomonas fragi*, Nashif and Nelson *(10)* found that the greatest production of extra-cellular lipase in 3 days occurred at 15° C. or below. Little lipase was produced at 30° C. or above. Greater lipase production was associated with increased *Ps. fragi* populations but was not closely proportional. Nashif and Nelson *(11)* observed that reduced pH caused by extensive growth of *Streptococcus lactis* in cream did not result in any appreciable inhibition of the growth of *Ps. fragi* but did interfere with the lipase of *Ps. fragi*, which showed no measurable activity below pH 4.9. When cream and butter were used as substrata, the lipase was active at a pH range from 4.9 to 8.2 with an optimum at 5.7 to 6.6 when incubated at 36° C for 24 hours. Nelson *(12)* reported the lipase of *Geotrichum candidum* to be inactive at pH 4.0 and destroyed at pH 3.0. The lipase in filtrates from cultures of *G. candidum* was active over a pH range of 5.0 to 8.0 and a temperature range of 20° to 37° C., with the optimum at 30° C. Hillig *et al. (6, 7, 8, 9)* determined the water-insoluble acid (WIA) content of numerous samples of commercial cream and butter and recommended a maximum permissible value of 400 mg. of WIA per 100 g. fat. Babel *(3)* reported no significant difference in the WIA values of butters made from cream held at 55° and 75° F. and suggested that the lipase is inhibited by rapid souring of the cream. Purko *(14)* found that high WIA values resulted when sterile cream was inoculated with strains of *G. candidum*. In studying conditions influencing *S. lactis* activity, Tarassuk and Smith *(15)* observed that rancid milk had an inhibitory effect on *S. lactis*, and Costilow and Speck *(4)* reported that caprylic, capric, and lauric acids inhibited *S. lactis*.

Received for publication May 2, 1955.

[1] Journal Paper No. J-2761 of the Iowa Agricultural Experiment Station, Ames. Project No. 1050.

[2] Present address: Dairy Department, Michigan State College, East Lansing.

EXPERIMENTAL PROCEDURE

It was desired to determine lipolysis, proteolysis, organism population, pH, and organoleptic grade resulting from the growth of *S. lactis*, *Ps. fragi*, and *G. candidum* individually in sterile cream incubated at various temperatures. The two latter organisms were also combined with *S. lactis* in order to observe the effect of the presence of *S. lactis* on the activity of these organisms in cream.

The organisms were isolated from raw milk or cream and activated by successive transfers in lactose nutrient broth prior to use. Grade A 35% cream was placed in 1-l. Erlenmeyer flasks and sterilized by steaming for 1 hour on each of three successive days. Analyses of uninoculated controls incubated at 10° and 30° C. showed that this method of heating accomplished sterilization and inactivation of enzymes. Inoculation was with 0.1 ml. of 18-hour broth culture. Three flasks were inoculated with *S. lactis*, three with *G. candidum*, and three with *Ps. fragi*. Also, three flasks were inoculated with *S. lactis* and *G. candidum* and three with *S. lactis* and *Ps. fragi*. A flask containing each organism or combination was incubated at 10°, 20°, and 30° C. Sterile burettes or large pipettes were used to secure samples for analyses immediately before and after incubation and at 1, 3, 5, 7, and 10-day intervals.

WIA analyses for lipolysis measurement were performed by the A.O.A.C. *(2)* method and free tryptophan for proteolytic measurement by the Duggan *(5)* method. Organism counts were obtained by Standard Methods *(1)* procedures in all instances where applicable. Plates for mold counts were incubated at 25° C. for 5 days. Plates for all other counts were incubated at 32° C. for 48 hours. When special media for differentiation were used, duplicate standard agar plates were prepared. *S. lactis* was easily distinguished from *G. candidum* by colony appearance. *Ps. fragi* in the presence of *S. lactis* was determined by addition of 1 part crystal violet dye to 125,000 parts of agar. This dye concentration inhibited *S. lactis* without interfering with *Ps. fragi*.

Organoleptic grade is indicated on the right side of each graph, the USDA[3] grading system being used. Cream samples were analyzed for organism counts, WIA, tryptophan, pH, and grade value at each sampling interval. Figures are presented which indicate each of the values determined during the incubation period.

RESULTS

The changes occurring in WIA, tryptophan, pH, organoleptic value, and organism counts when sterile cream was inoculated with *S. lactis* are shown in Figure 1. At all three temperatures the free tryptophan increased through the first 5 days and then decreased to approximately the original value. The trend of the WIA values is of no consequence in quality, but uniformity of pattern seems to be significant. At all three temperatures there was a slight decrease on

[3] Since completion of this phase of the work, USDA has announced a new grading system which eliminates C. G. (Cooking Grade) but leaves the other grades fundamentally the same.

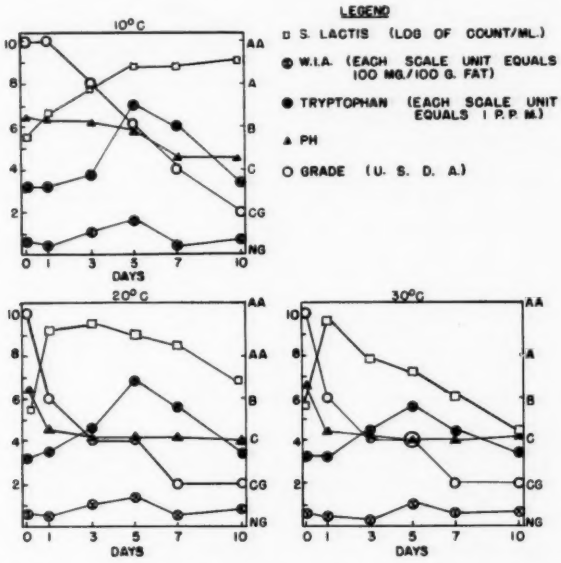

FIG. 1. WIA, tryptophan, pH, grade values, and organism counts of cream containing *S. lactis*.

the first day, then an increase to a maximum at 5 days, followed by a definite decline and subsequent slight increase. The same general pattern of activity for WIA and tryptophan values was observed with a number of different strains of *S. lactis*. Deterioration in organoleptic quality was related to increases in cell population and decreases in pH but not to fluctuations in WIA or tryptophan values.

Figure 2 shows the changes in WIA, tryptophan, organoleptic value, and organism counts resulting from the inoculation of sterile cream with *G. candidum*. The mold population increased in the same general pattern at all three temperatures with the rate and amount of fat hydrolysis increasing as the temperature increased within the range studied. At 20° and 30° C. the fat hydrolysis was sufficient to cause a slight drop in pH. Changes in tryptophan value were of no consequence, for the only high value occurred at 30° C. after the cream had deteriorated below an acceptable grade. Organoleptic deterioration was greater as the temperature increased and was related to high WIA values and mold population.

The changes occurring in WIA, tryptophan, pH, organoleptic grade and *S. lactis* and *G. candidum* counts when sterile cream is inoculated with both of these organisms are shown in Figure 3. A comparison of the population curves in Figures 1, 2, and 3 indicates that *S. lactis* exhibited practically no influence on the rate of increase or maximum population attained by *G. candidum*. However, these figures show that the presence of *G. candidum* reduced the rate of decline of *S. lactis* count at 20° and 30° C. A comparison of the pH curves shows

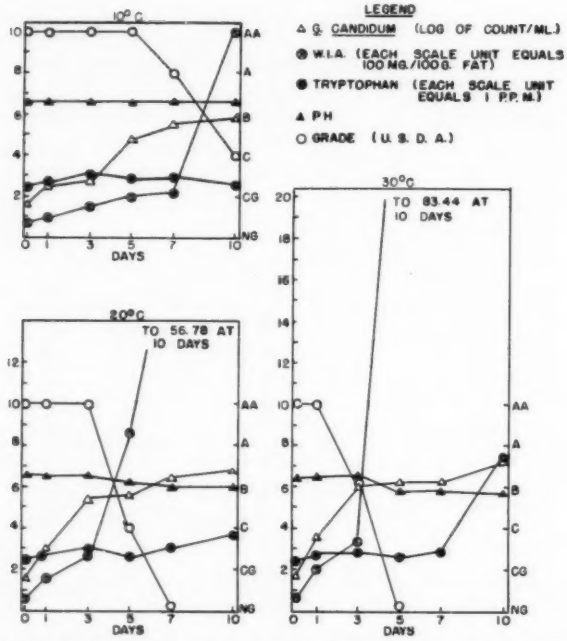

FIG. 2. WIA, tryptophan, pH, grade values, and organism counts of cream containing *G. candidum*.

that the decrease occurring in the presence of the two organisms is in response to *S. lactis*. The WIA curves in Figures 1, 2, and 3 indicate that *S. lactis* has a considerable inhibitory effect on the lipase of *G. candidum*, probably due to the reduced pH. In experiments that are not graphically illustrated it was demonstrated that a weak strain of *S. lactis*, which did not rapidly reduce the pH, exhibited very little inhibitory effect on the lipase of *G. candidum*. At 10° C., in the presence of both organisms, the WIA increased to 234 mg/100 g. fat, as compared to 1,027 mg/100 g. fat produced by *G. candidum* alone.

As shown in Figure 3, at 20° and 30° C. there was an abrupt increase in WIA between the third and fifth day, followed by a decrease on the tenth day. Attention is directed to the WIA curves of Figure 1 (*S. lactis* only), where the fluctuations are similar but less extreme.

Decrease in oleic acid, the principal WIA component, in the presence of *S. lactis* was demonstrated by adding known quantities of oleic acid to inoculated sterile cream, the WIA content of which was known. A consistent decrease occurred extending through the fifth day, the amounts being 211, 143, and 148 mg/100 g. fat at 10°, 20°, and 30° C., respectively.

Examination of Figures 1, 2, and 3 indicates that fluctuations in tryptophan values were in response to *S. lactis* activity. Figure 3 suggests that the initial organoleptic deterioration was closely related to the early organism population

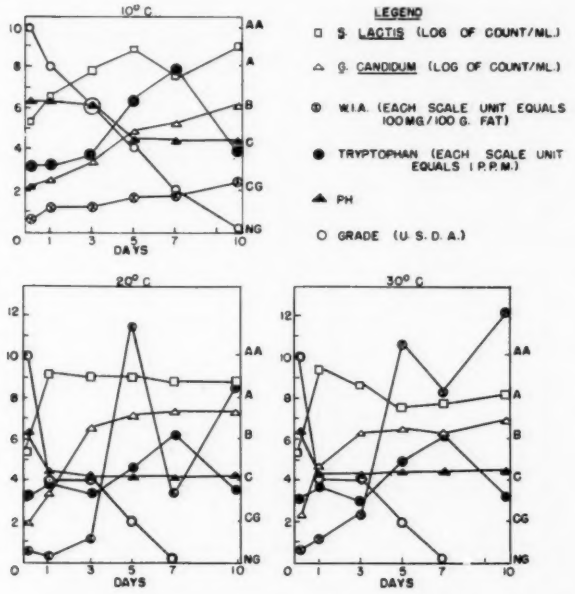

FIG. 3. WIA, tryptophan, pH, grade values, and organism counts of cream containing *S. lactis* and *G. candidum*.

increase and pH decline, with a subsequent quality decline being associated with increases in WIA and tryptophan values.

When sterile cream was inoculated with *Ps. fragi*, the changes in WIA, tryptophan, pH, organoleptic grade, and *Ps. fragi* count are shown in Figure 4. Maximum population was attained on the third day at 10° and 20° C. and on the first day at 30° C. The greatest maximum population occurred at 20° C., and the maximum at 10° C. was greater than at 30° C. There was no appreciable population decline at any temperature during the 10-day period. *Ps. fragi* was extremely lipolytic, and after the third day the WIA values increased greatly at all three temperatures. At 10° C., *Ps. fragi* was even more lipolytic than *G. candidum*. *Ps. fragi* was also quite proteolytic, the maximum free tryptophan values at 10° and 20° C. being substantially greater than at 30° C. The lower value at 30° C. is probably due to protease inhibition caused by greater free fatty acid accumulation and low pH resulting from more lipolysis at the higher temperature. Organoleptic deterioration seemed to be more closely related to increases in WIA and free tryptophan than to any other factor considered. Keeping quality was only slightly better at 10° than at 20° and 30° C.

The changes occurring in WIA, tryptophan, pH, organoleptic grade, and *S. lactis* and *Ps. fragi* counts when sterile cream was inoculated with both of these organisms are shown in Figure 5. A comparison of Figures 1, 4, and 5 shows that the presence of *S. lactis* exhibited a pronounced inhibitory effect upon

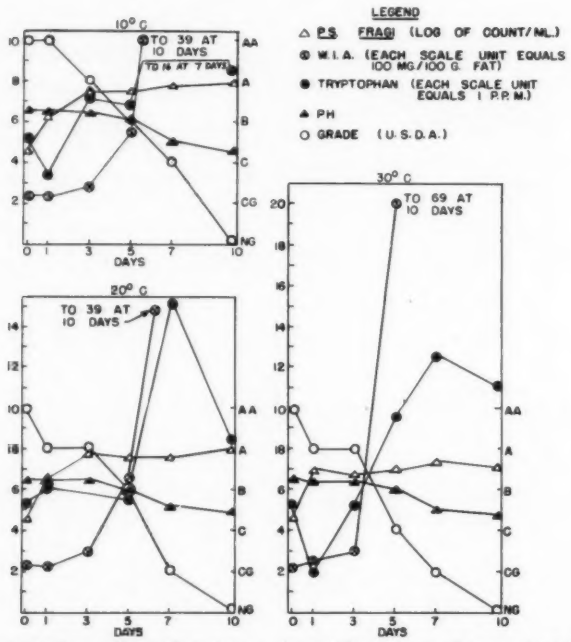

FIG. 4. WIA, tryptophan, pH, grade values, and organism counts of cream containing *Ps. fragi*.

Ps. fragi population at all three incubation temperatures. When associated with *S. lactis*, the maximum *Ps. fragi* counts attained were much lower and there was a numerical decline during the later stages of holding, which did not occur when *Ps. fragi* was grown alone. At 30° C., *S. lactis* caused the virtual disappearance of *Ps. fragi*, the counts being 10 and 14 per milliliter on the seventh and tenth days, respectively. *S. lactis* growth was normal at each of the three temperatures, indicating that the association with *Ps. fragi* produced no effect on *S. lactis* population. The pH decline was in response to normal *S. lactis* development.

The inhibitory effect of *S. lactis* upon *Ps. fragi* becomes more evident when the WIA curve is examined at each of the three temperatures. At 20° and 30° C. the influence of *S. lactis* was sufficient to practically inactivate any lipase elaborated from *Ps. fragi*, which is in extreme contrast with the high lipase activity encountered when *Ps. fragi* was inoculated alone. In Figure 5, at 10° C. the lipase was able to cause considerable fat hydrolysis, although barely more than half as much as resulted when *Ps. fragi* was grown alone. The maximum *Ps. fragi* population attained was substantially higher, and the pH decline caused by *S. lactis* was lower at 10° than at 20° or 30° C. However, the greater *Ps. fragi* population represents the most logical explanation for the higher WIA value, because the WIA increase did not begin until the third day, at which time the pH was down to 4.22. Utilization of WIA was again apparent, with the WIA decrease appearing on the first day at 30° C. and on the third day at 10° and 20° C.

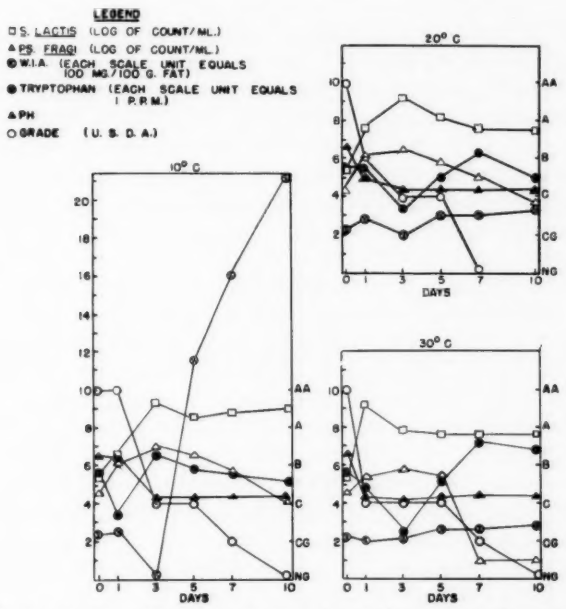

FIG. 5. WIA, tryptophan, pH, grade values, and organism counts of cream containing *Ps. fragi* and *S. lactis*.

The proteolytic characteristic of *Ps. fragi* was subordinated by *S. lactis* at all three temperatures. Organoleptic grade deterioration did not seem to be closely related to any one factor except that the early decline corresponds to the organism population increase and deterioration at 10° C. was associated with the high WIA value.

DISCUSSION

When pure cultures of *G. candidum* and *Ps. fragi* were inoculated into sterile cream, flavor defects were not apparent at WIA values up to 400 mg/100 g. fat, which is the maximum tolerated by the Federal Food and Drug Administration. The lowest WIA value which was associated with rancid flavor was 840 mg/100 g. fat with *Ps. fragi*. These samples contained no other off-flavor and were organoleptically acceptable as Grade C. The lowest WIA value at which *G. candidum* produced a moldy flavor was 2,337 mg/100 g. fat. Moldy flavors did not appear until after the presence of mold could be detected by careful scrutiny; however, the mold would have been less apparent if the samples had been stirred more frequently. Production of moldy flavor and WIA was closely related to *G. candidum* population. The WIA values produced by *G. candidum* in sterile cream compare favorably with results by Purko *et al. (14)*.

When *G. candidum* and *Ps. fragi* were each combined with *S. lactis* and inoculated into sterile cream, a rancid flavor appeared at substantially lower WIA values than prevailed when the lipolytic organisms were not associated

with *S. lactis*. In numerous instances a rancid flavor occurred at WIA values below 400 mg/100 g. fat when *S. lactis* was associated with the lipolytic organisms. When *S. lactis* and *G. candidum* were combined, a moldy flavor occurred at WIA values as low as 868 and 1,067 mg/100 g. fat. Decreases in WIA associated with the presence of *S. lactis* may be related to the appearance of rancid flavor at low WIA values. In an experiment with several strains of *S. lactis* greater decreases in WIA occurred with more vigorous strains. The appearance of the initial decrease was coincident with the attainment of maximum cell population. Addition of oleic acid to cream caused no reduction in the activity of *S. lactis*, and availability of oleic acid in abundant amount (approximately 600 mg/100 g. fat) resulted in a WIA decrease that was quantitatively greater than normal. Utilization of long-chain fatty acids by *S. lactis* is the most logical explanation for the fluctuating WIA values encountered during the incubation periods. Peters *et al. (13)* also encountered decreases of WIA in the presence of *S. lactis* and suggested the possibility of fatty acid utilization by the organism. When *S. lactis* was combined with lipolytic organisms, the rancid flavor occurring at low WIA values may have been due to the disappearance of the long-chain fatty acids while the short-chain fatty acids continued to accumulate as fat hydrolysis progressed. This opinion is supported by the work of Tarassuk and Smith *(15)*, who observed an increase in surface tension, due to utilization of long-chain fatty acid, when *S. lactis* was grown in milk.

The optimum temperature for activity of lipase enzyme elaborated from the strain of *Ps. fragi* used in this experiment was substantially higher than the optimum growth temperature of the organism. These results are in agreement with those of Nashif and Nelson *(10, 11)*, who reported a temperature of 15° C. or below, depending upon the individual strain, to be most favorable for production of lipase by *Ps. fragi* and found the maximum activity of this lipase occurred at 40° C. when a coconut oil substrate was used.

The amount of proteolysis produced by *Ps. fragi* was closely related to cell population, which was greater at 10° and 20° than at 30° C. This quantitative correlation suggests that the protease of this strain of *Ps. fragi* was fairly equally active over the temperature range of 10° to 30° C.

When *S. lactis* and *Ps. fragi* were combined, the lipase and protease of *Ps. fragi* may have been inhibited by the low pH induced by lactic acid. However, in the samples incubated at 20° and 30° C. there is a possible fallacy in this conclusion because *S. lactis* inhibited *Ps. fragi* cell population. Probably the cell population of *Ps. fragi* at 20° and 30° C. was insufficient to elaborate a functional quantity of enzymes. In the 10° C. sample containing *S. lactis* and *Ps. fragi*, there is sufficient reason to conclude that low pH partially inhibited the lipase and protease enzymes, although substantial fat hydrolysis occurred at pH 4.22 and 4.46. *Ps. fragi* attained sufficient population at 10° C. to provide a functional quantity of enzymes, but because of the reduced pH the activity of lipase and protease at this temperature was much less than when *Ps. fragi* was grown alone.

Combining *S. lactis* with *G. candidum* caused a numerical stimulation of *G. candidum* at all three temperatures. This may be due to the preference of the

mold for the low pH. In most instances mold counts on acidulated potato dextrose agar were slightly higher than on T.G.E.M. agar; however, this variation was not consistent. The disappearance of WIA in the presence of *S. lactis* was less apparent in the presence of *G. candidum*, probably because WIA was being produced continuously by the mold.

Despite the fact that *S. lactis* inhibited the lipase of *Ps. fragi* and *G. candidum*, the rate of organoleptic grade deterioration was greater at all temperatures when *S. lactis* was combined with each of these organisms because of the acid produced.

The considerable fluctuations which occurred in quantities of WIA and free tryptophan during holding of the cream limit the ability of the methods to accurately assess quality. During normal holding periods, organism activity could cause the WIA content of a particular sample of cream to fluctuate above and below the standard established by the Federal Food and Drug Administration.

SUMMARY AND CONCLUSIONS

When inoculated into sterile cream *Geotrichum candidum* produced maximum lipolysis and cell population at 30° C. *Pseudomonas fragi* produced maximum population at 20° C. and maximum water-insoluble acids at 30° C., indicating that the optimum temperature for the lipase action of *Ps. fragi* was above the optimum temperature for organism reproduction. More rapid organoleptic grade deterioration at 30° C. indicated that quality decline was more intimately associated with enzyme activity than with organism population. Rancid flavors occurred in cream at lower WIA values when *Streptococcus lactis* was combined with *Ps. fragi* or *G. candidum* than when the lipolytic organisms were grown alone. Decreases in WIA in sterile cream inoculated with *S. lactis* were encountered in several instances, and amounts of decreases were quantitatively measured by adding known quantities of oleic acid.

The presence of *S. lactis* and the accompanying lowering of pH reduced the lipase activity and WIA production of *G. candidum* and *Ps. fragi* and the activity of the protease of *Ps. fragi*. The presence of *S. lactis* was inhibitory to the population development of *Ps. fragi* but stimulated the population development of *G. candidum*.

Fluctuations in WIA and free tryptophan values, attributed to organism activity, occurred during incubation of inoculated cream.

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A QUANTITATIVE EVALUATION OF CHANGES OCCURRING DURING HEAT TREATMENT OF SKIMMILK AT TEMPERATURES RANGING FROM 170° TO 300° F.[1]

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Continuous or high-temperature, short-time methods of heating milk have almost entirely replaced the batch methods in milk processing plants. However, there is little published information concerning many of the changes milk undergoes when heated for various periods at temperatures between 200° and 300° F. A small-tube heat exchanger known as the Mallorizer was used by Hetrick and Tracy *(10, 11, 12)* to define the heat inactivation curves of phosphatase, lipase, and the heat denaturation of albumin and globulin. Herreid *et al. (9)* have used this heater in studies of the flavor and physical properties of cream. Data have been presented for pasteurization of milk *(18)* and the effect of heating in the Mallorizer at a temperature of 300° F. on the electrophoretic patterns of skimmilk proteins *(17)*.

It was the purpose of the present study to secure information concerning the effect of heating skimmilk at temperatures ranging from 170° to 300° F. on certain of the oxidation-reduction systems, denaturation of the serum proteins, and baking quality.

MATERIALS AND METHODS

High temperature tubular heater. To secure the data desired, it was necessary to construct a laboratory tubular heater capable of very accurately controlled heat treatments over a wide range of temperatures and holding times. Furthermore, it was desired that the heating and cooling times be as brief as possible. The apparatus, constructed as shown in Figure 1, consists of three major parts, the heating, holding, and cooling sections.

The heating section, consisting of two stages, was constructed of 67-in. lengths of 5/16-in. O.D., 16-gauge polished stainless steel tubes enclosed in ¾-in. standard iron pipes. Steam is supplied to the first stage through a pneumatic steam pressure controller (Taylor Pressure Controller 10RF), which can be adjusted to control the temperature of the milk from the first stage. Steam to the second stage is supplied through a pneumatic valve controlled by a proportional-reset-rate controller-recorder (Taylor Transit Tri-Act Controller, model 2A-329RF, and Taylor Tri-Act Recorder 82J-F). The temperature of the milk from the second stage is measured by the helium-filled bulb which actuates the

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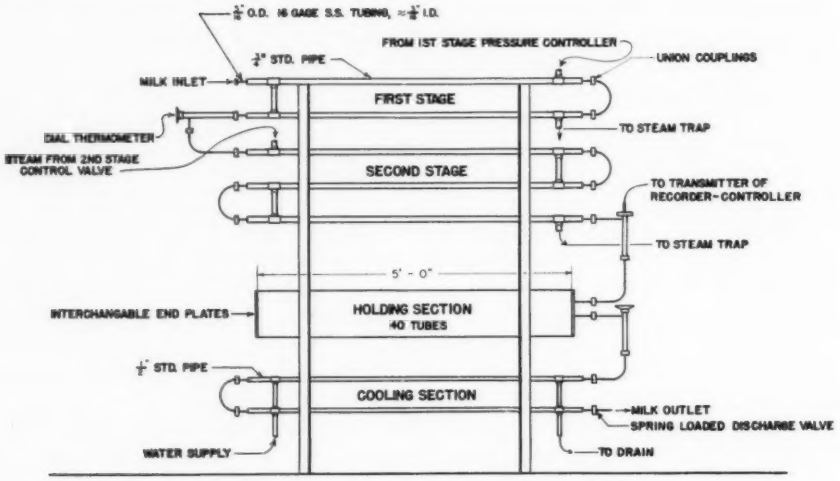

FIG. 1. Diagram of high temperature heat exchanger.

transmitter (Taylor Transaire Temperature Transmitter, 317RG) of the control system. This system controls the temperature of the milk to within ±1° F. of the desired temperature over a range of 170° to 300° F.

The holding section consists of forty 60-in. lengths of ⅜-in. I.D. polished stainless steel tubes, which are mounted in special double tube sheets to allow for individual expansion and contraction of the tubes. The nest of tubes is enclosed in an 8-in. standard iron pipe, which may be partially evacuated to reduce the heat loss during the holding period. Header plates containing various combinations of grooves may be used on the holding section to give holding times varying from about 6 to 100 seconds, or the holding section may be by-passed by a 3/16-in. I.D. tube, which gives a holding time of about 1 second. The milk is metered to the heater by a small positive pump at a rate of 5.2 lb. per minute.

The cooling section consists of two lengths of 5/16-in. O.D., 16-gauge, polished stainless steel tubing enclosed in ½-in. standard iron pipes.

Approximately 0.72 second is required for the milk to pass through each tube of the heating or cooling sections and about 0.3 second for each return bend. The volumes of the wells of the two high-temperature thermometers were included in calculating the holding times.

Source and treatment of the skimmilk. Most of the results reported in this paper were obtained on a single lot of bulked Grade A milk secured from a local source. Additional lots of milk from the same source were used to corroborate certain aspects of the data, particularly the baking results.

The fresh raw whole milk was put through a separator in which all parts coming in contact with milk were of stainless steel. The total solids and butterfat

contents of the skimmilk were determined by the Mojonnier method and the nitrogen distribution was obtained by the methods of Rowland *(16)* and Harland and Ashworth *(5)*. The skimmilk was cooled and stored over night at 38° F. before processing. Sixty samples were secured from the tubular heater representing six holding times, 0.96, 6.1, 15.7, 30.0, 63.6, and 96.9 seconds, and ten temperatures, 180°, 190°, 200°, 210°, 220°, 230°, 240°, 260°, 280°, and 290° F. Additional samples were heated at 300° F. for some holding times. Also, samples were heated at 170° and 185° F. for periods of 5, 10, 15, 20, and 30 minutes in stainless steel test tubes and a constant temperature water-bath as described by Harland *et al. (7)*.

Estimation of serum proteins. The undenatured serum protein content of the raw and heated milk samples was estimated, with minor variations, according to the turbidimetric method of Harland and Ashworth *(6)*. In the present work the results are expressed in terms of percentage denaturation of the heat labile serum proteins. The standard reference curve was based on the turbidity secured with the raw milk used (no denaturation), with a portion of the same milk after heat treating for 20 minutes at the temperature of boiling water (100% denaturation), and with appropriate mixtures of the raw and heated milk. The turbidity was developed in the diluted filtrates (2 ml. + 10 ml. saturated NaCl solution) by the addition of two drops of 10% HCl and inversion of the cuvette. The inversion was repeated before determination of the percentage transmission at 420 mμ.

Ortho-iodosobenzoate titer. The iodimetric method of Larson and Jenness *(13, 14, 15)* was used to estimate the total sulfhydryl content of the raw milk immediately after separating and of the heated samples after storage at 35° F. for 3 days with occasional shaking to provide time for oxidation of the heat-activated –SH groups.

Thiamine disulfide reducing capacity. The sulfhydryl content of each sample was estimated immediately after the heat treatment by the thiamine disulfide method of Harland and Ashworth *(4)*.

Acid ferricyanide reducing capacity. The extent of the browning reaction during the various heat treatments of the skimmilk was estimated by the Chapman-McFarlane ferricyanide method *(1)* essentially as modified by Choi *et al. (2)* except that a reaction time of 20 minutes at 50° C. and pH 6.6 was used as recommended by Crowe *et al. (3)*.

Bread baking tests. The standardized laboratory baking test, essentially as described by Larson *et al. (15)*, was employed to evaluate the quality of the fluid samples. In all cases 53.5 ml. of skimmilk was used per 100 g. of flour (approximately equivalent to 5 g. of solids). The bromate level was 1 mg. per 100 g. of flour. The doughs were mixed for 2.5 minutes and fermented for 2 hours.

Two loaves from a single mixing of dough were baked for each heated sample of skimmilk on each of two different days. Thus, four loaves were obtained for each sample of skimmilk. Most of the heat treatments and baking tests were repeated on another lot of skimmilk.

EXPERIMENTAL RESULTS

Composition of original skimmilk. The total solids and fat contents of the principal lot of skimmilk used in this study were 9.12 and 0.08% (Mojonnier), respectively. As shown in Table 1, the total nitrogen content (Kjeldahl) of the

TABLE 1

Kjeldahl nitrogen distribution in the skimmilk fractionated by two methods (mg. per ml.)

Component	Rowland	Harland-Ashworth
Total nitrogen	5.25	—
Noncasein N	1.16	0.97
Nonprotein N	0.26	0.26
Total SPN[a]	0.90	0.71
Heat labile[b] SPN	0.69	0.64
Per cent of SPN denaturable	76.5	90.3

[a] Serum protein nitrogen.
[b] Used synonymously with "denaturable" in this paper.

skimmilk was 5.25 mg. per milliliter, and the total and heat labile serum protein nitrogen contents were, respectively, 0.71 and 0.64 mg. per milliliter according to the Harland-Ashworth procedure *(5)*.

Serum protein denaturation. The times and temperatures necessary to denature 10, 75, and 80% of the heat labile milk serum proteins are shown in Figure 2. There is a curvilinear relationship between the log of the time and the temperature for a given extent of serum protein denaturation. For 10% denaturation, a temperature of 175.5° F. is required for 1.0 minute, 192.5° F. for 0.1 minute, and approximately 245° F. (extrapolated) for 0.01 minute. For 80% denaturation a temperature of 172.2° F. is required for 30 minutes, 196.2° F. for 3.0 minutes, and 298° F. for 0.3 minutes. Since 90.3% of the serum proteins in this lot of skimmilk was heat denaturable (Table 1), the curves in Figure 2 designated 10, 75, and 80% denaturation actually represent, respectively, 9.0, 67.7, and 72.2% denaturation of the total serum proteins.

Ortho-iodosobenzoate titer. The times and temperatures of heat treatment necessary for rendering 20, 35, 50, and 65% of the milk serum protein –SH groups (IBRS) susceptible to oxidation by atmospheric oxygen are indicated in Figure 3. The raw milk contained 0.30 meq. of –SH per liter. For 20% activation of the –SH groups, a temperature of 177° F. is required for 100 seconds, 194° F. for 10 seconds, or 223° F. for 1 second. Typical treatments necessary to promote oxidation of 65% of the –SH are 195° F. for 100 seconds, and 300° F. for 14 seconds. The maximum activation attainable is about 80% of the total *(15)*.

Thiamine disulfide reducing capacity. The times and temperatures of heating required for "liberation" of the "free" sulfhydryl groups (TDRS) from skimmilk are indicated in Figure 4. To secure 0.127 meq. of –SH per liter of milk, typical heat treatments required are 192° F. for 100 seconds, 220° F. for 10 seconds, and 320° F. (extrapolated) for 1.0 second. Data are also presented for the treatments necessary to secure 0.159 meq. of –SH. The maximum –SH con-

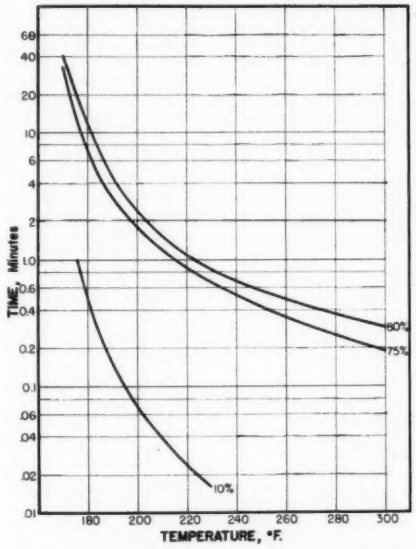

FIG. 2. Relation between time and temperature required for various percentages of denaturation of the milk serum proteins as measured by the Harland-Ashworth method.

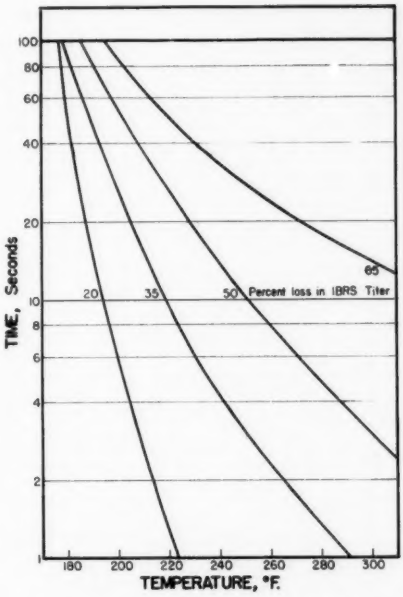

FIG. 3. Relation between time and temperature required for activation of protein sulfhydryl groups in skimmilk as measured by loss in iodosobenzoate-iodine reducing capacity.

tent obtained was 0.178 meq. per liter, which is somewhat higher than any results previously reported *(8)*.

Acid ferricyanide reducing capacity. As shown in Figure 5, the higher heat treatments produced small amounts of the products of browning that reduce ferricyanide. To obtain a reducing capacity of only 5×10^{-5} moles of ferrocyanide per liter of milk, representative heat treatments are 246.5° F. for 50 seconds, 275° F. for 25 seconds, and 293° F. for 10 seconds. Treatments at 230° F. for as long as 30 seconds or at temperatures up to 280° F. for 6 seconds produce no measurable quantities of these reducing substances.

Baking quality of skimmilk subjected to high-temperature, short-time heat treatments. The loaf volumes (most of the values represent the mean from eight loaves) are presented as a function of temperature for each of five holding times in Figure 6. The two lots of skimmilk used gave very closely comparable results. The minimum temperature necessary to secure a relatively satisfactory loaf volume of 740 cc., as read from the curves, was 218° F. for 97 seconds, 233° F. for 64 seconds, 250° F. (estimated) for 30 seconds, 260° F. for 16 seconds, and 300° F. (extrapolated) for 6 seconds. These heat treatments are shown in Table 2 with the corresponding percentage denaturation of the milk serum proteins.

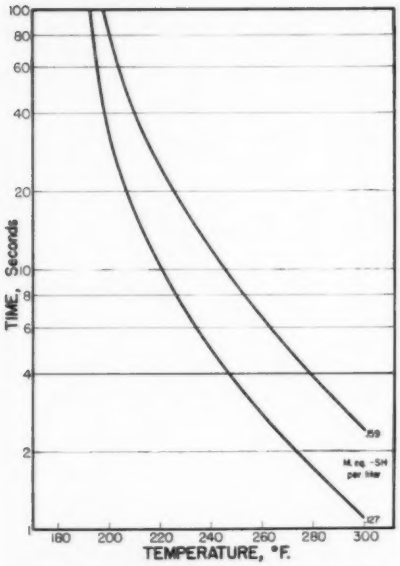

FIG. 4. Relation between time and temperature required for activation of protein sulfhydryl groups in skimmilk as measured by increase in thiamine disulfide reducing capacity.

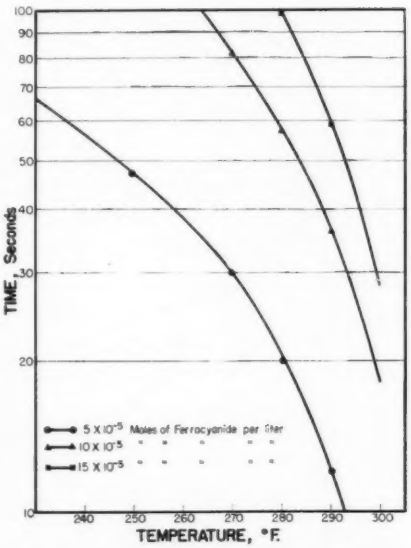

FIG. 5. Relation between time and temperature for the production of acid ferricyanide reducing substances in skimmilk.

They are also plotted in Figure 7 in comparison with the heat treatments necessary for 80% denaturation of the heat labile serum proteins. It is apparent that there is not a constant relationship between the baking quality, as measured by loaf volume, and the extent of serum protein denaturation since the two curves diverge at higher temperatures.

DISCUSSION AND SUMMARY

These results were obtained for the most part on one lot of milk but have been confirmed with other samples and are believed to be representative.

The present data extend to higher temperature ranges than those previously reported *(7)* for the time-temperature relationships in the heat denaturation of milk serum proteins. The previous data secured over the temperature range of 145° to 175° F. indicated a straight line semi-logarithmic relationship of temperature to time at any given level of serum protein denaturation with a "Z" value of 13.5. Present data show that the relationship becomes curvilinear as the temperature increases with a "Z" value of approximately 19 at the temperature range of 175° to 194° F., and still higher at higher temperatures. Such curvilinearity is not unexpected in view of the multiplicity of proteins in the serum protein mixture and the possibilities for different reactions in different ranges of temperature. At higher temperatures the time required for any given degree

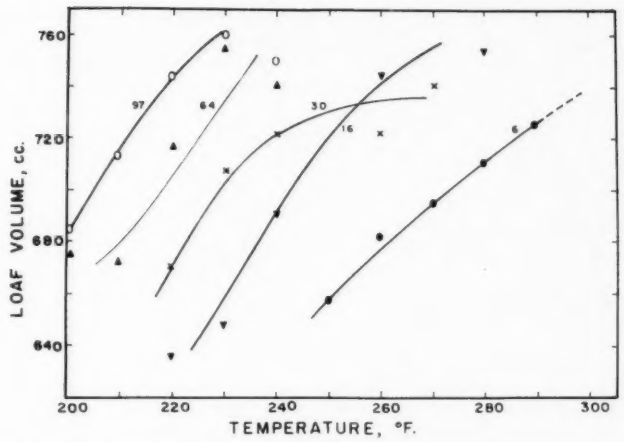

FIG. 6. Effect of various high-temperature, short-time heat treatments on the baking quality of skimmilk.

of serum protein denaturation is greater than that indicated by an extrapolation of a plot based on data secured at lower temperatures. Obviously, such extrapolation should be avoided if the necessary data are obtainable.

The only comparable data for serum protein denaturation in the range of times and temperatures covered in this study are those secured by Hetrick and Tracy *(12)* with the Mallorizer. They determined "albumin plus globulin" by the Rowland method, which should be comparable to the "heat labile serum protein" reported herein. Their results tend to parallel ours but they report less drastic heat treatment for a given extent of denaturation. For example, for 75% denaturation, Figure 2 indicates that 1.7 minutes was required at 200° F., but Hetrick and Tracy's data indicate that this extent of denaturation was accomplished with 0.9 minutes at 200° F. The reason for such a large discrepancy is not known.

The heat treatments necessary for the production of near maximum amounts

TABLE 2

Heat treatments of milk that are adequate for bread baking and the corresponding percentage denaturation of the serum proteins

Time[a]	Temperature[a]	Denaturation of serum proteins
(sec.)	*(° F.)*	*(%)*
97.0	218	84
64.0	233	85
30.0	250[b]	77
16.7	260	71
6.0	300[c]	67

[a] Time and temperature required for a loaf volume of 740 cc.
[b] Estimated.
[c] Extrapolated value.

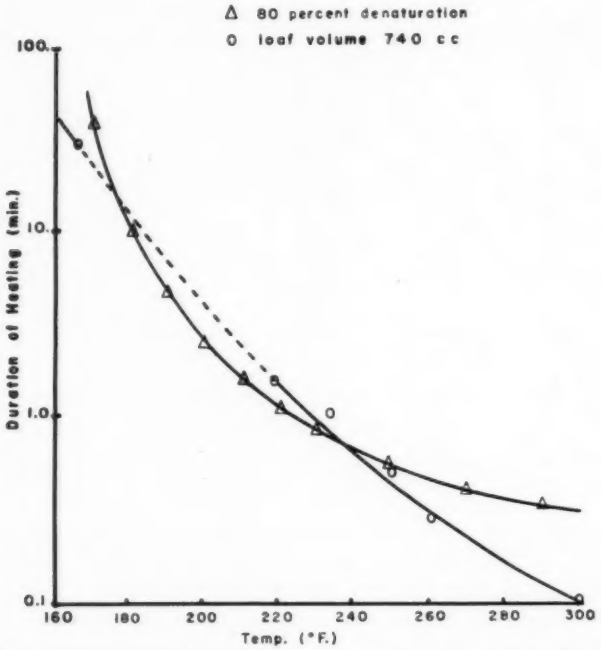

FIG. 7. Time temperature relationships for 80% denaturation of the milk serum proteins and a loaf volume of 740 cc.

of free sulfhydryl groups in skimmilk have been defined. These data should be of interest to manufacturers of dry whole milk where maximum resistance to oxidation is desired. The time which is required at any given temperature to cause a measurable amount of sugar-protein interaction (AFRS) is about the same as that necessary to produce essentially maximum SH activity. The downward curve obtained in the log-time-temperature plot is evidence that the sugar-protein interaction may be, to some extent, "autocatalytic," or that other reactions come into play at higher temperatures. Close to maximum SH activity can be obtained with little AFRS production. Additional heat treatment produces relatively large amounts of AFRS with little increase in SH activity.

The loaf volume depressant factor in skimmilk can be inactivated sufficiently by high-temperature, short-time heating to secure satisfactory loaf volume. The holding time required decreased with increase in temperature. Some evidence is presented that inactivation of the loaf depressant factor is not proportional to total serum protein denaturation. Nevertheless, a specification of 80-85% serum protein denaturation should insure adequate baking quality.

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papers approved for publication. The views or conclusions contained in this report are those of the authors. They are not to be construed as necessarily reflecting the views or endorsement of the Department of the Army. The support of the Minnesota Institute for Research is gratefully acknowledged. The bread was baked by Calvin G. Norris.

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LEUCINE METABOLISM OF *STREPTOCOCCUS LACTIS* VAR. *MALTIGENES*.[1] I. CONVERSION OF ALPHA-KETOISOCAPROIC ACID TO LEUCINE AND 3-METHYLBUTANAL

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Streptococcus lactis requires leucine for multiplication *(1, 10)*, but no report has been found regarding the leucine requirement of *S. lactis* var. *maltigenes*, which according to Hammer and Baker *(6)* is capable of producing a malty aroma in milk cultures. Jackson and Morgan *(8)* identified the substance responsible for the malty defect as 3-methylbutanal, the precursor of which was found to be leucine.

The present work is a study of: *(a)* the essentiality of leucine for *S. lactis* var. *maltigenes*, *(b)* the ability of the α-keto acid analog of leucine to substitute for the amino acid, *(c)* the production of α-ketoisocaproic acid from leucine by resting cells of *S. lactis* and *S. lactis* var. *maltigenes*, and *(d)* the formation of leucine from its keto acid analog in the presence of glutamic acid by resting cells of *S. lactis* and *S. lactis* var. *maltigenes*.

EXPERIMENTAL PROCEDURE

Cultures. Two strains of *S. lactis* and three strains of *S. lactis* var. *maltigenes* isolated from raw milk samples were used in the leucine requirement experiment. Throughout the study the cultures were maintained in sterile homogenized milk. The three malty strains produced a malt-like aroma in milk but otherwise behaved similarly to the *S. lactis* cultures with respect to multiplication at 10°, 40°, and 45° C. and ammonia production from arginine. The two nonmalty strains were designated L_2 and L_{31} and the three malty strains as M_1, M_3, and M_{22}. In the experiments involving the biosynthesis of leucine from α-ketoisocaproic acid only two cultures, L_2 and M_1, were used because of the limited quantity of the keto acid available.

Synthetic media. The basal synthetic medium used throughout was that of Niven *(10)* modified as follows: *(a)* The proportions of the amino acids found in casein *(5)* were substituted at levels comparable to those in casein hydrolyzate, and *(b)* sodium acetate and sorbitan monooleate were added to the medium as recommended by Collins *et al. (4)*. The media were adjusted to pH 6.8, tubed in 10-ml. amounts and autoclaved at 15 lb. (121° C.) for 11 minutes. A solution of asparagine and glutamine was sterilized by filtration and added aseptically to the tubes subsequent to autoclaving.

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[1] This paper was prepared from data collected by the senior author to be presented in a thesis to the Graduate School of the University of Connecticut in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Nutritional studies involved five synthetic media: *(a)* complete basal, *(b)* basal minus leucine, *(c)* basal minus isoleucine, *(d)* basal minus valine, and *(e)* basal minus leucine plus sodium α-ketoisocaproate. In preparation of the latter the sodium salt of the keto acid was added to autoclaved *b* and the medium was resterilized by filtration. The media were incubated at 32° C. for 48 hours before inoculation to insure sterility.

Inoculation technique and growth measurement. Each medium was inoculated originally with a 4-mm. loopful of an 18-hour milk culture and incubated at 32° C. for 48 hours. This was followed by three serial 48-hour subcultures in each medium, one loopful of the previous 48-hour culture being used as the inoculum. The growth responses of the various strains after four transfers in the different media were expressed as per cent light transmission as measured in a Coleman Universal spectrophotometer at 610 mμ.

Preparation of resting cell suspensions. Saline suspensions of *S. lactis* and *S. lactis* var. *maltigenes* were prepared from agar slants. Two ml. of these suspensions was added to penicillin culture bottles containing 125 ml. of trypticase soy agar (B.B.L.) supplemented with 0.5% lactose, 0.5% agar, and 0.0001% pyridoxal hydrochloride. The agar cultures were incubated for 15 hours at 37° C. and the cells were harvested and washed thoroughly in 0.67 *M* phosphate buffer at pH 7.0 *(14)*. Approximately 1-ml. quantities of packed cells were suspended in 25 ml. of either phosphate buffer at pH 7.0 or Tris [2 · amino-2-(hydroxymethyl)-1,3-propanediol] at pH 8.3 containing: *(a)* 10 mg. L-leucine, *(b)* 5 mg. sodium α-ketoisocaproate and 10 mg. L-glutamic acid, and *(c)* no substrate added. The suspensions were incubated for 2 hours at 37° C.

Chromatographic analysis of acid and neutral carbonyl derivatives. After the incubation period the cells were removed by centrifugation. Ten ml. of 2% 2,4-dinitrophenylhydrazine in 2 *N* HCl was added to 23 ml. of the clear supernatants. (The remainder of each supernatant was reserved for amino acid chromatography.) These mixtures were allowed to remain at room temperature for 1 hour. The 2,4-dinitrophenylhydrazones were extracted with ether and the ether was evaporated. The acid and neutral hydrazones were then partitioned between 1 *N* ammonium hydroxide and chloroform as recommended by Cavallini and Frontali *(3)*. The volume of the ammonium hydroxide was limited to 4-6 ml.

The ammonia extracts were spotted in 0.04-ml. amounts on sheets of Whatman No. 1 paper. The papers were formed into cylinders and chromatographed in cylindrical jars as described by Jackson and Morgan *(8)*. The developing solvent was *n*-butanol-ethanol-water (4:1:5 by volume, *3*). The papers were allowed to equilibrate in the presence of the aqueous phase from 1 to 2 hours before the alcohol-rich phase was added.

The chloroform extracts were evaporated to dryness over hot water and the residues were taken up in 2 ml. of benzene-heptane (1:1 by volume). Each benzene-heptane extract was freed of excess 2,4-dinitrophenylhydrazine by adsorption on a 15 × 60 mm. column of anhydrous magnesium sulfate. The derivatives were eluted from the column with additional solvent under 3 to 5 lb. air pressure. The derivative solutions were evaporated to a volume of 2 ml. and

spotted in 0.04 ml. quantities on Whatman No. 1 paper. The neutral carbonyl 2,4-dinitrophenylhydrazones were chromatographed in methanol heptane (1:2 by volume) by the method of Heulin *(7)*.

Chromatographic analysis of amino acids. The clear supernatants were spotted in 0.04-ml. quantities on a 6½ × 19½ in. strip of Whatman No. 1 paper. The paper was allowed to equilibrate in an atmosphere of ammonia and phenol-saturated water for 1 hour, developed with water-saturated phenol for 24 hours by the descending technique, dried, and sprayed with 0.1% solution of ninhydrin in ethanol. The paper was kept in the dark for 24 hours before examination for amino acid spots.

RESULTS AND DISCUSSION

The growth responses of the test cultures after the fourth transfer in the five synthetic media as measured by per cent light transmission are given in Table 1. These indicate the essentiality of leucine, isoleucine and valine for the five cultures, and the ability of α-ketoisocaproate to fulfill the leucine requirement for cultures L_2 and M_1.

TABLE 1

Essentiality of leucine, isoleucine, and valine for S. lactis *and* S. lactis *var.* maltigenes *and the replacement of leucine with α-ketoisocaproate*

	Media				
Cultures	Basal	Basal minus leucine	Basal minus isoleucine	Basal minus valine	Basal minus leucine plus α-ketoisocaproate
L2	43[a]	100	100	98	44
131	37	100	100	99	
M1	48	100	100	98	51
M3	53	100	100	99	
M22	45	98	98	100	

[a] Per cent light transmission.

Strassman *et al. (11)*, in studying the biosynthetic mechanisms involved in the formation of valine, leucine, and isoleucine in *Torulopsis utilis*, using isotopic methodology, found evidence that the leucine carbon chain consisted of an acetyl group attached to the isobutyl moiety of valine. The pathway of leucine biosynthesis as proposed by them involves the condensation of the methyl carbon of acetyl CoA with α-ketoisovalerate to yield an hydroxy acid, which was converted to α-ketoisocaproic acid, and this by transamination with glutamic acid was converted to leucine. The results in Table 1 indicate that neither isoleucine nor valine satisfies the leucine requirement of *S. lactis* and *S. lactis* var. *maltigenes* and strongly suggest that both convert α-ketoisocaproate to leucine.

Further evidence of this is shown in *B* and *C* of Figure 1, which is a tracing of the chromatogram of the amino acids involved when resting cells of the lactic cultures were incubated at 37° C. for 2 hours at a pH of 8.3 with α-ketoisocaproate and glutamic acid. Although other amino acids spots, *viz.*, alanine, appeared on the original chromatogram, they were not considered significant because the

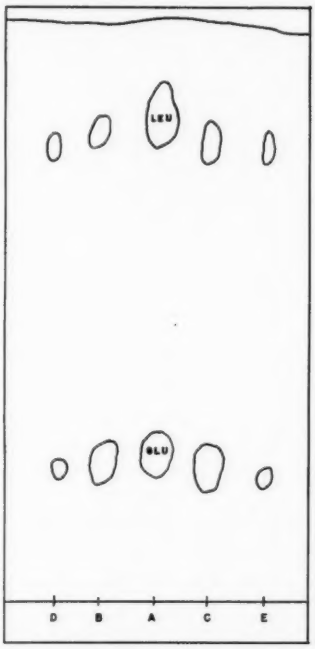

FIG. 1. Chromatogram of L-glutamic acid and L-leucine (A); and of leucine formed during incubation of *S. lactis* var. *maltigenes* and *S. lactis* cells with α-ketoisocaproate in the presence of glutamic acid (B) and (C) and with no substrate added (D) and (E). (Approximately 1-ml. packed cells suspended in 25-ml. of buffer with 10 mg. of L-amino acid and 5 mg. α-keto-isocaproate.)

controls *D* and *E* showed corresponding spots. Much larger amounts of leucine were noted in *B* and *C* than in the controls *D* and *E*. This constitutes direct evidence of the biosynthesis of leucine from α-ketoisocaproate and suggests that both organisms possess amino acid transaminase. Bonner *(2)*, Umbarger and Adelberg *(12)*, and Umbarger and Magasanik *(13)* have reported that mutant strains of *Escherichia coli* and *Neurospora crassa* have the ability to form amino acids from their keto acid analogs.

If the amino group from glutamic acid is transferred to α-ketoisocaproate, it would be expected that leucine and α-ketoglutaric acid would result. Judging from the size and intensity of the spot of the 2,4-dinitrophenylhydrazones of the acid carbonyl fractions as shown in Figure 2, there appeared to be little or no increase in α-ketoglutaric acid formation in *F* and *G* over that in *D*, *E*, *H*, and *I*. It is possible that some of the α-ketoglutaric acid had undergone degradation and the products of such degradation were not demonstrable by the method used. The fact that both organisms form α-ketoisocaproic acid from leucine is demonstrated in *D* and *E* of Figure 2. This is indicative of the reversibility of the keto acid to amino acid reaction.

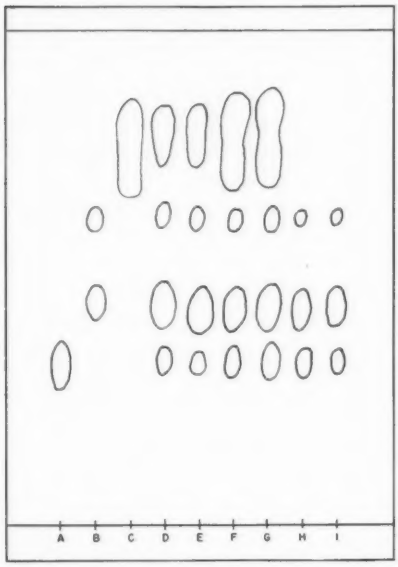

FIG. 2. Chromatogram of 2,4-dinitrophenylhydrazones of α-ketoglutaric acid (A), pyruvic acid (B), and α-ketoisocaproic acid (C); and of the acid-carbonyl compounds formed during incubation of *S. lactis* and *S. lactis* var. *maltigenes* cells with L-leucine (D) and (E), α-ketoisocaproate plus L-glutamic acid (F) and (G) and no substrate added (H) and (L). (Approximately 1-ml. packed cells suspended in 25 ml. of buffer with 10 mg. L-amino acids and 5 mg. α-ketoisocaproate.)

The two spots appearing in *B* of Figure 2 may be explained by isomerization of the phenylhydrazone of pyruvic acid *(3)*. This tendency to separate into two forms was also noted in the present work with α-ketoisocaproate and accounts for elongation of spots of this compound in *C*, *F*, and *G*.

The dependency on pH of the amino acid transaminase of *S. lactis* and *S. lactis* var. *maltigenes* cells does not appear to be very great, as judged from a limited number of experiments run with these organisms. No more activity was observed at pH 8.0-8.5 than at 7.0-7.5. These results indicate a similarity between these organisms and *S. faecalis*, as reported by Liehstein *et al. (9)*.

The 2,4-dinitrophenylhydrazones of the neutral carbonyl compounds formed when cells of *S. lactis* and *S. lactis* var. *maltigenes* were incubated with L-leucine and its keto acid analog are shown in Figure 3. Spots of a derivative which ran with a known derivative of acetone appeared in all preparations. This is at variance with the results of Jackson and Morgan *(8)*, who in a similar experiment found acetaldehyde but no acetone in all instances. There appears to be no valid explanation of this difference at present. It is evident from *E* and *G* in Figure 3 that *S. lactis* var. *maltigenes* converts both the amino acid and the keto acid to 3-methylbutanal, which has been identified by Jackson and Morgan as the compound responsible for the malt-like aroma and flavor of milk cultures of *S. lactis*

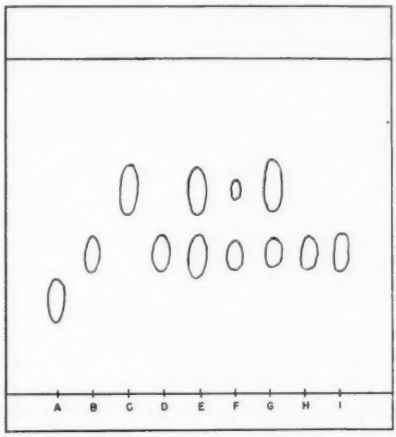

FIG. 3. Chromatogram of 2,4-dinitrophenylhydrazones of acetaldehyde (A), acetone (B), 3-methylbutanal (C) and of the neutral carbonyl compounds formed during incubation of *S. lactis* and *S. lactis* var. *maltigenes* cells with L-leucine (D) and (E), α-ketoisocaproate plus L-glutamic acid (F) and (G), and no substrate added (H) and (I). (Approximately 1-ml. packed cells suspended in 25 ml. of buffer with 10 mg. L-amino acids and 5 mg. α-ketoisocaproate.)

var. *maltigenes*. *S. lactis*, on the other hand, formed no aldehyde from L-leucine and little or none from the keto acid. This indicates an important physiological difference in the two organisms. These results suggest possible pathways of leucine degradation by the two organisms, which may be schematically represented as follows:

$$\underset{\text{Leucine}}{\overset{\text{I}}{\rightleftarrows}} \underset{\text{α-ketoisocaproic acid}}{\overset{\text{III}}{\rightarrow}} \underset{\text{3-methylbutanal}}{\overset{\text{IV}}{\rightarrow}} \text{other products}$$

$$\text{II} \downarrow$$

$$\text{other products}$$

The present work has established that both organisms possess the mechanism for step I and that *S. lactis* var. *maltigenes* follows steps I and III. *S. lactis* may degrade leucine through steps I, III, and IV or alternatively through I and II. Further investigation of the degradation of α-ketoisocaproic acid by *S. lactis* and *S. lactis* var. *maltigenes* is in progress.

SUMMARY

S. lactis and *S. lactis* var. *maltigenes* require leucine, isoleucine, and valine for multiplication. Evidence is presented which indicates that α-ketoisocaproic acid satisfies the leucine requirement of both organisms.

Resting cells of the two organisms synthesize leucine from α-ketoisocaproate in the presence of glutamic acid. The malty variant also converted the keto acid

as well as leucine to 3-methylbutanal. Although both organisms were shown to degrade L-leucine to α-ketoisocaproic acid, *S. lactis* formed little or none of the malty aldehyde from either the amino or the keto acid.

The physiological difference between *S. lactis* and its malty variant appears to lie either in a difference in ability to decarboxylate α-ketoisocaproic acid or in ability to degrade 3-methylbutanal.

ACKNOWLEDGMENT

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ISOLATION AND CHARACTERIZATION OF SOME OXIDATION PRODUCTS ASSOCIATED WITH OXIDIZED FLAVOR[1]

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Oxidized flavor is a troublesome defect in some dairy products. The work of Thurston and Barnhart *(35)* has indicated that milk lecithin is the source of the flavor. Swanson and Sommer *(33)* have shown that the development of the oxidized flavor is primarily due to the partial oxidation of the milk phospholipids. In this paper the expression "oxidized flavor"[4] consequently refers to the defect resulting from the partial oxidation of the milk phospholipids.

The purpose of this study was to isolate and characterize some of the steam distillable compounds from oxidized milk phospholipids.

EXPERIMENTAL PROCEDURE AND RESULTS

Isolation of milk phospholipids. Milk phospholipids were separated from dried buttermilk (Land O' Lakes, Minn.) by ethanol-ether extraction and then purified by fractional precipitation with acetone. This was accomplished by placing 500 ml. of 1:1 ethanol-ether mixture and 500 g. of the dry buttermilk in a 1-gal. glass jar and shaking the mixture mechanically for 3 hours. The extract was filtered and then concentrated by distilling off the solvent. The recovered solvent was used in the extraction of subsequent lots. To the fatty residue in the distilling flask, acetone was now added, the fat going into solution and the phospholipids remaining undissolved. After decanting off the acetone-fat solution (containing a minimum amount of the original ethanol-ether), the phospholipid residue was purified as follows: The residue was dissolved by the addition of ether and with the aid of mechanical agitation. The aim was to use only enough ether to effect complete solution. To this solution, acetone was added with stirring to precipitate the phospholipids, and acetone addition was continued until the precipitation appeared to be complete. The white precipitate was recovered by filtration. This purifying procedure was repeated four more times. Finally the white precipitate was dried acetone-free in a vacuum desiccator. The yield was 0.4% of the buttermilk powder. Twenty-eight g. of purified phospholipids were so prepared and stored under vacuum at 0-5° C. The isolated phospholipids may have been contaminated with triglycerides, since they were later found to contain 3.68% phosphorus and 1.64% nitrogen.

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[1] The data in this paper are taken from a thesis presented by the senior author in partial fulfillment of the requirements for the degree of Doctor of Philosophy, University of Wisconsin.

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[3] Deceased.

[4] Not to be confused with "oxidized fat flavor" resulting from the oxidation of the milk glycerides.

Oxidation of the phospholipids. For the purpose of oxidation, a 0.04% phospholipid suspension was prepared and submitted to a multiplicity of treatments. Effects of vitamin C, copper and heating on the oxidation of the phospholipid suspension were studied. As shown in Table 1, the more intense oxidized flavor was obtained when copper and vitamin C were added to the suspension, the mixture heated to 87° C. for 10 minutes and stored for 24 hours at 0-5° C. This procedure was adopted for the preparation of the subsequent batches of oxidized phospholipid suspension.

TABLE 1

Effects of different treatments on oxidized flavor development in phospholipid suspensions

Treatment of 100 ml. 0.04% phospholipid	Degree of oxidized flavor	
	24 hours	48 hours
Nil	S	S
25.0 mg. vit. C	+	++
3.0 p.p.m. copper	++	+++
25.0 mg. vit. C + 3.0 p.p.m. copper	+++	++++
3.0 p.p.m. copper + 87° C/10 min.	++++	++++
3.0 p.p.m. copper + 25.0 mg. vit. C + 87° C/10 min.	+++++	+++++

S = Slight oxidized flavor.
+ = Increasing degree of oxidized flavor.

Steam distillation of oxidized flavor compounds. Batches (1 l.) of oxidized phospholipid suspension were steam distilled in conventional manner from a 3-l. round bottom flask. Distillate was collected at a rate of 1 ml. per minute to a total of 500 ml. per batch. A batch of nonoxidized phospholipid steam distilled in a similar manner gave a distillate that was negative to the 2,4-dinitrophenylhydrazine test. Oxidized phospholipid suspension and steam distillate from oxidized phospholipid suspension, added to milk samples at the rate of 2% and 5%, had the immediate effect of establishing a typical oxidized milk flavor.

Chemical properties of distillate. A series of chemical tests was run repeatedly on the distillate, and typical data are summarized in Table 2.

Formation of derivatives. The typical odor of oxidized flavor was lost by virtue of the 2,4-dinitrophenylhydrazine reaction. This indicated that the car-

TABLE 2

Chemical properties of fractions resulting from the steam distillation of an oxidized phospholipid suspension

Test on 10 ml. sample	Water control	Residue	Distillate	Oxidized suspension
TBA[a] *(13)*	0.000	0.045	0.160	0.202
Benedict's *(29)*	−	−	−	−
Potassium permanganate[b] *(23)*	0	8	10	20
Bromine[b] *(23)*	0	3	6	7
Iodoform *(23)*	−	−	slight	slight
Ferric chloride *(23)*	−	−	−	−
2,4-dinitrophenylhydrazine *(23)*	−	+	+	+

[a] Optical density at 535 mμ.
[b] Drops of reagent needed.
− Negative.
+ Positive.

bonyl compounds are significant contributors to oxidized flavor. This was also supported by the fact that the steam distillate of a nonoxidized phospholipid suspension did not give rise to any hydrazone formation.

Unknown derivatives were prepared by collecting the steam distillate into a half saturated acid-ethanolic solution of 2,4-dinitrophenylhydrazine. The steam distillate collected into the hydrazine solution was in the ratio of 10 to 1 (by volume). Some formation of hydrazones occurred immediately. The pH of the solution was brought below 3.5 with hydrochloric acid and the mixture was kept at 0-5° C. for 2 days. The hydrazones were collected by suction on a sintered glass filter crucible and dried. The solid hydrazones were finally dissolved out of the filter with ethyl ether. The ethereal solution of hydrazones was kept for chromatographic separation.

Known derivatives of formaldehyde and acetone were prepared by a minor modification of the method described by McElvain *(23)*.

Chromatographic separation of 2,4-dinitrophenylhydrazones. Bentonite (Fisher Scientific Co.) and Celite (Johns-Manville Co. No. 545) were mixed in a 2 to 1 ratio (by weight) and activated at 200° C. for 24 hours. The column was prepared in a Pyrex tube, 12 mm. × 30 cm. The bottom was plugged with a filter paper disc over a perforated rubber stopper fitted with a 3-mm. glass tube outlet. A slurry of the adsorbent was prepared with ethyl ether and poured into the column. After partial settling, a filter paper disc was placed on top of the adsorbent to prevent disintegration of the column. A pressure of 40 cm. of mercury was applied until all the supernatant ether had percolated into the adsorbent.

One ml. of a saturated ethereal solution of the hydrazones mixture was pipetted on top of the column. The pressure was applied until the solution had percolated. Three 0.5-ml. portions of developing solvent (5% acetone in ethyl ether) were successively allowed to percolate with pressure in order to rinse in all the hydrazones. Then the column was filled to the top with the developing solvent, and the pressure was applied during the development of the chromatogram. Five bands were well resolved, and their colors in order of their elution were: yellow, red, orange, orange, red. The first three bands were eluted through the column. Only the center of the eluted bands was collected as fractions. The intensity of the fourth band was not sufficient to permit the collection of enough material for characterization purposes. The bands were identified as fraction numbers in order of their elution. By the time the first three bands were eluted, the last band was still at the top of the column. It was eluted with ethanol after extruding and sectioning the column. About 100 chromatograms were so developed in order to obtain enough material for characterization. Although the hydrazones were not recorded quantitatively, the yield was approximately 500 mg. The predominance of the fractions was in the following order: Fraction 1, Fraction 3, Fraction 5, Fraction 2. To attain purification, each fraction was chromatographed independently in a similar manner.

Recrystallization of the hydrazones. The hydrazone solutions were filtered, concentrated, and recrystallized from ethanol until constant melting points were

obtained *(23)*. Fraction 1 did not crystallize from ethanol but remained as a dark red oil. Various solvents were tried, and the methanolic solution was found to yield satisfactory crystallization. Ethanolic solutions of 2,4-dinitrophenylhydrazones are known to change from yellow to red or to blue when they are made alkaline *(27, 32)*. This test was found positive and to give a reddish color when performed on each purified derivative.

X-ray diffraction. The X-ray diffraction data for the 2,4-dinitrophenylhydrazones of the four fractions and of undecanal were obtained with the use of the FeK_1 radiation. The X-ray data for the derivatives of Fraction 3 and of undecanal had some similarity.

Melting point. A copper-constantan thermocouple was used for the determination of the melting points in a 2.0 × 3.5 × 3.5-in. magnesia hot stage somewhat similar to that described by Vold and Doscher *(37)*. The thermocouple was satisfactorily calibrated with a series of chemical compounds of available purity. The melting point of the fractions, determined in the same manner, was recorded in Table 3, which includes also the color and form of the crystals as observed under the microscope.

Spectral transmittancy of the 2,4-dinitrophenylhydrazones. The transmittancy spectra of the 2,4-dinitrophenylhydrazones of the four fractions, acetone, and formaldehyde were taken in the ultraviolet range with a Beckman model DU spectrophotometer. The solvent used was 95% ethanol except for Fraction 1, which was in absolute methanol. A Corning No. 9863 Red-Purple Corex A filter was used between 320 and 400 mμ. The concentrations were adjusted at 356 mμ to the following optical densities: Fraction 1, 0.31; Fraction 2, 0.24; Fraction 3, 0.32; Fraction 5, 0.29; acetone, 0.22; formaldehyde, 0.40. The transmittancy curves for the above compounds are shown in Figure 1. The absorption maxima observed were at 365 mμ for Fraction 1, 366 for Fraction 2, 358 for Fraction 3, 368 for Fraction 5, 358 for acetone (literature, 360), 348 for formaldehyde (literature, 349). The light absorption maximum observed for the 2,4-dinitrophenylhydrazone of undecanal in 95% ethanol was at 358 mμ (optical density 0.30).

Elemental analyses. The elemental percentages as found and calculated for the 2,4-dinitrophenylhydrazones of the fractions 2, 3, and 5 are presented in Table 3. The data for Fraction 1 clearly were not satisfactory or adequate to account for the recorded properties, thus these data have been omitted.

DISCUSSION

The production of oxidized flavor compounds by oxidizing milk phospholipids is justified by the evidence in the literature that oxidized flavor in milk has its source in the phospholipid fraction. Josephson and Doan *(17)* were able to produce a typical oxidized flavor by heating a suspension of phospholipid in the presence of copper.

Steam distillation has been used by Mohr and Wellm *(24)* to isolate the oxidized flavor compounds as they occur in milk, but they did not succeed in identifying the substances on account of the small quantities involved.

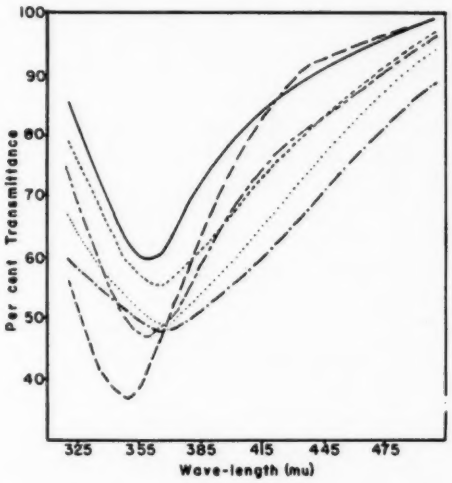

FIG. 1. Spectral transmittancy of 2,4-dinitrophenylhydrazones of: (————), acetone; (— — —), formaldehyde; (— · — · —), Fraction 1; (– – – –), Fraction 2; (— – — –), Fraction 3; (· · · ·), Fraction 5.

Flavor compounds arising from oxidized butterfat have been characterized in several instances. Iselin *(16)* claimed that the carriers of the organoleptic rancidity in animal fats are epihydrinaldehyde and free aldehydes such as enanthaldehyde (heptanal) and pelargonaldehyde (nonanal). Mundinger *(26)* obtained a positive 2,4-dinitrophenylhydrazine reaction in the steam distillate of oxidized butterfat. Van der Waarden *(36)* indicated the presence of epihydrinaldehyde, methyl ketones, and aliphatic unsaturated C_4 to C_8 aldehydes in the flavoring material of cold storage butter. He pointed out that the off flavor from butter could not be extracted with water. In line with this, Mulder *et al. (25)* observed that cold-storage defects are located in the fat whereas the metallic flavor compounds in butter are located in the serum. Henick *(14)* showed by infrared spectrophotometry that simple ketones and aldehydes and a conjugated ketone developed during the autoxidation of milk fat.

While this work was in progress, Keeney and Doan *(18, 19, 20)* reported their classical isolation from oxidized milk fat of four carbonyl compounds which had the following empirical formulae: $C_3H_{4\text{-}6}O_2$, $C_7H_{12}O$, $C_9H_{16}O$, and $C_{12}H_{20\text{-}22}O$. The first compound has been postulated to be 2-hydroxypropanal. The others have been characterized as unsaturated carbonyl compounds, the C_7 and the C_9 being ketones. They obtained $C_{10}H_{18}O$ (α-β-unsaturated carbonyl) upon prolonged distillation of oxidized milk fat. Kende *(21)* suggested that the tallowy taste in milk was due to elaidin.

In this study, the positive 2,4-dinitrophenylhydrazine reaction and the subsequent separation of 2,4-dinitrophenylhydrazones prove the presence of at least five carbonyl compounds in oxidized phospholipid. Unsaturation among these

TABLE 3

Properties of hydrazones

Parent compound	M.P. ° C.	Color	Crystal form[a]		Elemental percentages C[b]	H[b]	N[c]	O[d]	Empirical formulae for parent compound
Acetone	125	Yellow	Rectangular plates						
Formaldehyde	167	Yellow	Long needles						
Undecanal	104	Orange-yellow	Rectangular plates	Calculated:	58.27	7.48	15.99	18.26	$C_{11}H_{22}O$
Fraction 1	60	Yellow	Plates and needles						
Fraction 2	85	Orange-red	Irregular plates	Found:	56.82	6.85	12.80	23.53	$C_{15}H_{26}O_3$
				Calculated:	56.86	7.16	13.26	22.72	
Fraction 3	103	Orange-red	Rectangular plates	Found:	58.54	6.33	15.50	19.63	$C_{11}H_{22}O$
				Calculated:	58.27	7.48	15.99	18.26	
Fraction 5	333	Orange-red	Rectangular plates	Found:	53.30	6.08	23.60	17.02	$C_{22}H_{38}N_8O_2$
				Calculated:	53.39	6.06	23.81	16.74	
					53.03	6.12	23.19	17.66	$C_{10}H_{18}N_2O$

[a] Recrystallized from ethanol, except Fraction 1 from methanol.
[b] Performed by Dr. A. L. Wilds, Chemistry Dept., Univ. of Wisconsin.
[c] Performed by Micro-Tech. Laboratories, Skokie, Ill.
[d] Found by difference.

compounds is suggested by the positive bromine and potassium permanganate tests. A slight positive iodoform test is suggestive of the presence of a small amount of methyl ketone (s). The Benedict's test was negative, but, in view of the limited sensitivity of this test, the possibility of the presence of aldehyde among the flavor compounds is not eliminated.

Melting point properties for the identification of hydrazones are not too reliable. The diagnosis becomes complicated by the fact that many 2,4-dinitrophenylhydrazones have been reported to exist as modifications *(1, 4, 5, 6, 7, 8, 9, 11, 12, 15, 22, 30)* and to form solid solution with one another *(2)*.

It has been indicated that the color is an indication of the degree of unsaturation in the carbonyl compound *(3, 10, 28, 34)*. According to Braude and Jones *(3)*, derivatives of straight-chain saturated carbonyl compounds absorb at 356-360 mμ, whereas when the unsaturation is conjugated with the carbonyl group, the maximum light absorption is found in the region of 370 to 380 mμ. Roberts and Green *(28)* observed also that the increasing degree of unsaturation in the parent carbonyl compound causes shifts of the absorption maxima toward the longer wave lengths. They concluded from the study of 20 2,4-dinitrophenylhydrazones that the compounds with double bonds conjugated with the imino linkage absorbed at 377-379 mμ and those without conjugation absorbed at 349-363 mμ.

Elemental analyses indicated that the hydrazone of Fraction 2 (m.p. 85° C.) was that of a fifteen-carbon di-unsaturated carbonyl compound with two non-carbonyl oxygen atoms. The light absorption maximum of 366 mμ indicates unsaturation with no double bonds conjugated with the carbonyl group *(3, 28)*.

It is postulated that the hydrazone of Fraction 3 (m.p. 103° C.) was derived from undecanal. Both derivatives absorbed light at the same wave length. Their melting point, color, crystal form, elemental percentages, and X-ray diffraction data had great similarity. The limited quantity of the unknown fraction did not permit the determination of mixed melting point and other properties.

The melting point (333° C.) of Fraction 5 indicated a bis-hydrazone. The derivative, however, gave a reddish color when tested in alcoholic sodium hydroxide. According to Stadtman *(32)*, the formation of red color in alkaline alcohol is characteristic of simple aldehyde and ketone 2,4-dinitrophenylhydrazones, whereas the formation of blue color is generally associated with 2,4-dinitrophenylhydrazones such as bis-hydrazones. Neuberg and Strauss *(27)* have reported monohydrazones such as nitrophenylhydrazones giving high melting point and reddish color in sodium ethylate. On the assumption that the elemental analyses for this compound are valid, the parent compound calculated to correspond to a bis-hydrazone would be $C_{22}H_{38}N_5O_2$. The parent compound calculated to a monohydrazone would be $C_{10}H_{18}N_2O$. In both cases the parent compound is shown to contain nitrogen. If we assume that the nitrogen determination was incorrect and that the unknown compound contained no nitrogen, the hydrazone should contain O and N atoms in like numbers. Apportioning the unaccounted fraction [100 − (53.30 + 6.08) = 40.62] on the above basis would lead to 18.96% N and 21.66% O. On this basis the parent compound would correspond to $C_8H_{14}O$

(elemental percentages of derivative: 54.89 C, 5.92 H, 18.29 N, 20.89 O) as a monocarbonyl compound and to $C_{14}H_{28}O_2$ (elemental percentages of derivative: 53.05 C, 6.17 H, 19.04 N, 21.75 O) as a dicarbonyl compound. The light absorption maximum at 368 mμ indicates that there is no unsaturation conjugated with the carbonyl group (s). The data for Fraction 5 do not seem substantial enough to permit a single postulation for the parent compound.[5]

The adsorption of the hydrazones on bentonite falls in line with the findings of Smith and LeRosen *(31)* that the degree of adsorption paralleled inversely the length of the side chain. In this study the significant role of carbonyl compounds in the oxidized flavor as developed has been indicated. The same major carbonyl compounds were constantly formed upon limited oxidation of phospholipids. This is based upon the observation that five different bands of 2,4-dinitrophenylhydrazones resulting from the distillation of different batches of oxidized phospholipids have appeared with identical characteristics over the development of some 100 chromatograms. Further study, involving the isolation of the flavor compounds in larger quantity and the synthesis of the parent compounds to establish the exact structure of the oxidized flavor compounds, will be needed.

[5] One reviewer of this paper pointed out that in view of its strong adsorption on bentonite this compound might have been rearranged or decomposed by the time it was eluted.

SUMMARY

The limited oxidation of milk phospholipids yielded material which reproduced the typical oxidized flavor in milk. Isolation and characterization of the major oxidized flavor compounds showed that they are predominantly carbonyl compounds. Five different carbonyl compounds were evidenced by chromatography. The empirical formulae calculated for three compounds were $C_{15}H_{26}O_3$, $C_{11}H_{22}O$, $C_{22}H_{38}N_5O_2$ (as bis-hydrazone) and $C_{10}H_{18}N_2O$ (as monohydrazone). There is indication that the C_{15} was a di-unsaturated ketone without conjugation. The C_{11} was presumably undecanal.

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A METHOD FOR THE STUDY OF CELLULOSE DIGESTION BY WASHED SUSPENSIONS OF RUMEN MICROORGANISMS[1]

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Several methods have been developed for the study of in vitro cellulose digestion of the ruminant. Marston *(9)* used a procedure which appeared to simulate closely the natural environment in the rumen. His method was later improved by Louw *et al. (8)* by incubating rumen fluid in a semi-permeable bag suspended in a large volume of aqueous growth medium. This improved method prevents the accumulation of digested end-products, such as volatile fatty acids, in the bag so that the rate of digestion will not be inhibited. A similar method on a smaller scale was devised by Huhtanen *et al. (5)*. Another artificial rumen technique was developed by Burroughs *et al. (1)* for the study of cellulose digestion. In this method the rumen inoculum was diluted each day so that the nutrients originally present in the rumen fluid were gradually exhausted, thus making this method quite critical in evaluating the comparative merits of different feeds as sources of unidentified factors *(10)*. One limitation of this method, however, was the time required (5 to 10 days) in completing the fermentation test. Therefore, it appeared desirable to develop a method which not only would be sensitive enough to detect the effect of small amounts of unidentified factors stimulatory to cellulose degradation but at the same time would require a shorter fermentation period. To meet these requirements a method using washed suspensions of rumen microorganisms was developed. A description of this technique together with some of the factors that have been found to influence the rate of cellulose digestion by rumen microorganisms is presented in this paper.

EXPERIMENTAL PROCEDURE

Rumen contents obtained from a fistulated steer were strained through four layers of cheesecloth, which constituted the first step in obtaining the rumen inoculum in liquid form. In a typical experiment 1,200 ml. of rumen fluid were collected from a fistulated steer. It was centrifuged at a speed of about 1,000 r.p.m. for 1 minute. By this process partially digested feed particles in the liquid as well as most of the protozoa were sedimented and were discarded. The supernatant was then centrifuged again at a speed of 5,000 r.p.m. for 20 minutes (a Sharples super-centrifuge operating at a speed of 25,000 r.p.m. was found preferable when large volumes of rumen fluid were used). The resulting sediment, consisting principally of rumen bacteria, was suspended in 360 ml. of distilled water or a phosphate buffer at pH 7.0 and centrifuged again for 20 minutes at 5,000 r.p.m. The washing was repeated once more. The final sediment

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TABLE 1
Composition of nutrient solution

Chemicals	g. per 2 liters
Na_2HPO_4	0.631
KH_2PO_4	0.303
$NaHCO_3$	5.25
KCl	0.75
NaCl	0.75
$MgSO_4$	0.225
$CaCl_2$	0.075
$FeSO_4 \cdot 7H_2O$	0.015
$MnSO_4$	0.008
$ZnSO_4 \cdot 7H_2O$	0.008
$CuSO_4 \cdot 5H_2O$	0.004
$CoCl_2$	0.002
Urea	2.000

was suspended in 600 ml. of a nutrient solution prepared according to the following formula modified from Burroughs *et al. (2)* and shown in Table 1.

Three grams of purified cellulose (Solka-Floc) was added to the suspension, making the concentration of this insoluble cellulose 0.5%. The solution was bubbled with a stream of carbon dioxide gas for 10 minutes. The pH was adjusted to 7.0 with a saturated solution of sodium carbonate. No readjustment of pH was required during the course of digestion because at the end of a 24-hour incubation period the pH was about 6.6, which was still within the range for optimum cellulose digestion. Aliquots of 20 ml. each were pipetted into 75-ml. Pyrex centrifuge tubes. Each of these tubes was fitted with a rubber stopper and inlet and outlet glass tubings for bubbling the solution with a constant flow of carbon dioxide gas. The gas served to provide an anerobic condition as well as to agitate the solution. These tubes were incubated in a constant temperature water bath kept at 39° C. At the end of 24 hours the fermentation was terminated and cellulose was determined on the entire contents of each tube by using the procedure of Crampton and Maynard *(3)* with slight modifications.

In studying factors influencing cellulose digestion by this method, it was necessary only to add such factors into respective tubes and compare the degree of cellulose digestion obtained with cellulose digestion in control tubes without added factors. Usually triplicate tubes were run for the control as well as for each factor studied. When 0.5% cellulose was placed in the medium, approximately 60% digestion could be obtained in the control tubes by the end of 24 hours. The apparatus used in these studies is illustrated in Figure 1.

RESULTS AND DISCUSSION

Certain conditions must be maintained in the fermentation tubes if efficient cellulose digestion is to take place. The optimum pH for maximum cellulose digestion by washed suspensions during a 20-hour period was found to be from 6.8 to 7.6, as shown in Table 2.

Only when the pH was lower than 6.4 or higher than 8.0 was the percentage of cellulose digestion reduced to a considerable extent. The rumen microorgan-

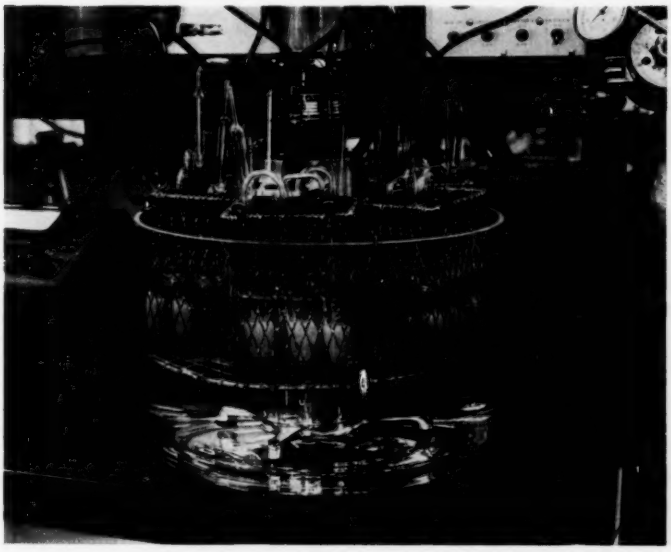

FIG. 1. Apparatus used for the study of cellulose digestion by washed suspensions of rumen microorganisms.

isms appeared to be able to tolerate a high pH better than a low pH. At the end of the 20-hour incubation period, the pH of all the tubes having an initial pH between 6.8 and 8.4 stayed between 6.7 and 7.1. Since this range was still adequate for optimum digestion, it was not necessary to readjust the pH during the course of digestion.

Most of the digestion runs were terminated at the end of 20-24 hours. With 0.5% of cellulose in the medium, vigorous digestion occurred between 16 and 20 hours incubation. The rate of digestion for 4-hour intervals is shown in Table 3.

The concentration of cellulose used in the medium also affected the amount of its digestion in 24 hours. Thus, it is seen in Table 4 that the greatest amount was digested when the medium contained 1% cellulose. However, on a percentage

TABLE 2

Influence of pH on cellulose digestion

pH	Cellulose digested[a]	Cellulose digested
	(g.)	*(%)*
5.6	0.0282	30.3
6.0	0.0443	47.8
6.4	0.0511	55.1
6.8	0.0599	64.5
7.2	0.0607	65.4
7.6	0.0586	63.2
8.0	0.0527	56.8
8.4	0.0488	52.5

[a] The initial amount of cellulose in each tube was 0.0928 g.

TABLE 3
Rate of cellulose digestion

Time	Cellulose digested[a]	Cellulose digested	Rate of cellulose digestion
(hr.)	*(mg.)*	*(%)*	*(mg/4 hr.)*
0	0	0.0	0
4	102	9.6	102
8	142	13.4	40
12	295	27.7	153
16	519	48.9	224
20	726	68.4	207
24	824	77.7	98

[a] The initial amount of cellulose was 1,060 mg.

basis, a more favorable digestion was obtained when the concentration of cellulose in the medium was less than 1%. Thus, it is seen that, in general, the less the concentration of cellulose is in the medium, the more complete is its digestion by the microorganism when the size of the inoculum is held constant.

The rate of cellulose digestion was also affected by the size of the inoculum or the concentration of rumen microorganisms used during incubation. Most of the experiments herein reported were based on the use of 20 ml. washed suspension of rumen microorganisms equivalent to 40 ml. of original rumen fluid taken from the animals. Table 5 shows the percentage of cellulose digested as influenced by the amounts of original rumen fluid used. It is apparent that the use of 40 ml. of rumen fluid was adequate to produce optimum digestion in 24 hours. However, it should be mentioned that in these experiments the rumen fluid samples were taken from a 1,000-lb. fistulated steer receiving a ration consisting of 6 lb. of corn, 2 lb. of soybean oil meal, 12 lb. of corn silage, and as much hay as he could eat. It is very likely that in different animals fed different rations the activity of the rumen microflora would be altered to some extent. Therefore, the amount of rumen fluid required to give an optimum digestion could conceivably vary with different conditions.

One of the advantages of using washed microbial suspension over the unwashed rumen fluid is that in the former method any unknown factors that might be present in the rumen fluid are washed out. The washed suspension is also comparatively free from any metabolic end-products that were produced by the microorganisms while they were in the rumen. Therefore, when an adequate nutrient solution is provided together with a substrate, in this case an insoluble

TABLE 4
Effect of substrate concentration on cellulose digestion

Cellulose in nutrient solution	Initial wt. of cellulose	Cellulose digested	Cellulose digested
(%)	*(g.)*	*(g.)*	*(%)*
0.25	0.0432	0.0327	75.7
0.50	0.0812	0.0466	57.3
0.75	0.1351	0.0857	64.6
1.00	0.1838	0.0984	53.6
1.25	0.2260	0.0862	38.1

TABLE 5

Effect of the concentration of rumen microorganisms on cellulose digestion

Rumen fluid	Initial amount of cellulose	Cellulose digested	Cellulose digested
(ml.)[a]	*(g.)*	*(g.)*	*(%)*
10	0.0894	0.0247	27.7
20	0.0932	0.0614	65.9
40	0.0961	0.0890	92.8
60	0.0960	0.0901	93.2
80	0.0948	0.0903	95.3

[a] Ml. of rumen fluid used in the preparation of 20 ml. washed suspension.

cellulose, the enzymes of the microorganisms begin to act on the substrate during the period of incubation. Any influences from unknown sources were reduced to a minimum by repeated washings of the rumen microorganisms. However, unnecessary repeated manipulations of them in the laboratory would decrease their activity.

It is seen from Table 6 that the reduction in cellulose digestion due to a second or even a third washing of the rumen microorganisms was relatively small when a solution adequate in minerals was used. However, the effect of thrice washing as compared to only once was deleterious when the nutrient solution was reduced in mineral concentration. Thus, it is apparent that this washed suspension technique is very sensitive for the in vitro study of mineral requirements of rumen microorganisms.

The use of washed suspension of rumen microorganisms in the study of their metabolic activity has furnished much valuable information regarding the reduction of nitrate to nitrite and ammonia *(7)*, the mechanism of the decarboxylation of succinic acid *(6)*, the fermentation of glucose and cellobiose *(11)*, and the catabolic reactions of various compounds *(4)*. The present technique appears to be useful in the study of various factors influencing cellulose digestion as well as the conditions necessary for maximum utilization of cellulose by rumen microorganisms. Although in vitro studies may not yield results that are directly applicable to in vivo conditions, it is, nevertheless, reasonable to suggest that such may be the necessary conditions that are likely to meet the needs of cellulolytic microorganisms in the rumen of live animals.

TABLE 6

Effect of washing of rumen microorganisms on cellulose digestion

	Reduced mineral solution[a]		Adequate minerals solution[b]	
	Cellulose digested		Cellulose digested	
	(g.)	*(%)*	*(g.)*	*(%)*
Washed once	0.0404	42.6	0.0658	69.5
Washed twice	0.0286	30.7	0.0613	62.4
Washed thrice	0.0155	15.8	0.0534	54.6

[a] The concentrations of chemicals, except those of phosphate and urea, were reduced to one-tenth of those shown in Table 1.

[b] The concentrations of minerals are given in Table 1.

SUMMARY

A technique based on the use of washed suspension of rumen microorganisms was developed for the study of in vitro cellulose digestion. When washed rumen microorganisms were suspended in 20 ml. of a mineral nutrient solution containing 0.5% of cellulose, approximately 60% of cellulose was digested during an incubation period of 24 hours. Conditions required for optimum cellulolytic activity, such as pH, concentration of the substrate, concentration of rumen microorganisms, and the duration of incubation, are given. The use of this technique in detecting unidentified factors, as well as in determining the mineral requirements for maximum utilization of cellulose by rumen microorganisms, was discussed.

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POPULATION AND PRODUCTION CHARACTERISTICS OF RED SINDHI CATTLE IN CEYLON

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The Tamankaduwa district in the dry zone of Ceylon has long been engaged in breeding cattle. The annual rainfall in this area averages 65 in., being heaviest during the northeast monsoon period from November to February, when 60% of the total precipitation occurs. There are no marked seasonal variations in temperature, which averages over 82° F., but day and night temperatures differ considerably. The maximum day temperature is around 95° F., and the minimum night temperature is about 68° F. Humidity during the dry months from March to October can be as low as 45%.

Tamankaduwa is now the home of a large herd of Red Sindhi cattle that has been built up by regular importations from India and Pakistan since 1937-38. These cattle are used primarily for milk production, though the bullocks are sometimes used for such agricultural operations as carting. The population changes that occurred in the Polonnaruwa herd, as it is called, provide interesting evidence on fecundity in tropical breeds, and in this work an analysis has been made of the mechanism of such changes. A study has also been made of the production statistics obtained from the herd. The results are set out in three parts:

a) Expansion of the herd up to 1953.
b) Possible expansion in the future.
c) Production statistics of the herd.

ANALYSIS OF DATA

Expansion of the herd up to 1953. Table 1 shows the yearly average population during different periods since the inception of the herd in 1937-38.

TABLE 1
Population changes in the Red Sindhi herd at Polonnaruwa, Ceylon (yearly average figures)

	Years			
	1938-41	1942-45	1946-49	1950-53
Total population (all ages)	168	457	653	734
Total females (all ages)	107	299	405	481

To account for this expansion, it was necessary to determine the prevailing mortality rates, rearing proportions, average rates of reproduction, and additions to the herd by purchase or importation.

Mortality among female calves born in the herd between 1938 and 1953, as measured by the percentage of females that die before calving, averaged 23%.

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Although the maximum rearing proportion attainable with this figure for heifer mortality would be of the order 0.36 to 0.37, the rearing proportion actually attained in the herd was only 0.19 for calves born between 1938 and 1949. An average rearing proportion of 0.19 means that it was only once in about five calvings that a cow produced a heifer calf which reached a lactation in the herd.

If the herd remained constant in size, the total reproductive rate, which is a product of the rearing proportion and the reproductive life, would be unity, and the reproductive life itself would be merely the reciprocal of the rearing proportion. But, as the Polonnaruwa herd was evidently expanding at a rapid rate, it was obvious that this relation would not hold, and the actual average reproductive life should be computed from individual animals. However, even this was not possible, since some heifers born in 1937-38 were still alive in 1953 and the average reproductive life of heifers born in any year can be measured only after all the members of the group have died. Evidently, the only method of explaining the mechanism of herd expansion was to estimate the partial reproductive rates in the different years, sum these over the whole period, and then compute the average reproductive life from the total reproductive rate thus estimated and from the rearing proportion. The partial reproductive rate r_{ab} may be described as the fraction of heifers calving in year a which produces a heifer calf calving in year b. The sum of the partial reproductive rates made in a given year, $\Sigma_a r_{ab}$, may have no biological meaning, but, as pointed out by Robertson and Asker *(8)*, "it is measurable instantaneously and is equal to the total reproductive rate if the latter is constant over a period." The sum of the partial reproductive rates for the different years from 1938 to 1949 was found to be 0.46 for the Red Sindhi herd under consideration. In practical terms this means that, on the average, about every two cows produced in their lifetime one heifer calf that came into milk in the herd.

A total reproductive rate of 0.46 and a rearing proportion of 0.19 yield an estimate of the probable reproductive life per cow of 2.42 calvings. The effect of this combination of factors on population trends in the herd would have been to produce a rapid decline in numbers. This may appear paradoxical in the light of the remarkable increase in size of herd from 1938 to 1949 reported in Table 1. However, large-scale importation of stock from various parts of India and Pakistan had featured so regularly in the development of the herd that not only the arrest of decline in population size but also the actual increase in numbers can be attributed to importation. Table 2 shows the total number of females imported during different periods.

To an investigator accustomed to accepted animal husbandry practices that require self-sufficiency in female replacement stock, the history of the Polon-

TABLE 2

Additions to herd by importation

	Periods			
	1938-41	1942-45	1946-49	1950-53
Total females imported	109	220	106	70

naruwa herd would be perplexing. The low rearing proportion and the short reproductive life show that existing resources were being depleted at a rapid rate while large-scale importation of stock, which incidentally had no production records or pedigree, was being resorted to in an attempt to increase the herd. It is therefore encouraging to note that a radical change in policy regarding rearing of replacement stock was formulated and implemented in 1950-51. This is reflected to some extent in the age-distribution of cows in milk in 1953, which is shown in Table 3. The corresponding distributions reported by Pettit *(6)* and by the English Milk Marketing Board *(5)* for several breeds are also presented in this table for comparison.

TABLE 3

Age distribution of cows in milk

Lactation	Red Sindhi herd (1953)	Pettit	M.M.B.
1st	24.9	23.5	25.6
2nd	24.9	22.5	21.6
3rd	12.9	20.6	16.9
4th	12.4	13.0	13.8
5th	9.2	8.2	9.2
6th	8.3	5.2	5.7
7th	0.9	3.0	3.1
8th	2.8	1.7	2.1
9th	1.8	0.9	1.2
10th and over	1.8	0.7	0.8

The three sets of figures appear very similar, and they indicate that the wastage rates now obtaining in the herd at Polonnaruwa are much the same as those obtaining in temperate countries. Moreover, from the provisional figures available in 1955, it also appears that a rearing proportion of 0.25 would probably be obtained for heifers born during the 1950-53 period as compared with 0.19 obtained earlier.

Of the many factors responsible for the progress made during the 1950-53 period, the consistent attempts to maintain about 70% of the adult female population in the herd in milk at all times and the consequent reduction in length of calving interval may be mentioned as most important. To this must be added the considerable drop in calf mortality in recent years.

Possible expansion in the future. As it is intended that the Polonnaruwa herd should be built up to a strength of 1,000 females, it was decided to investigate how and when this expansion might be achieved without continuing to resort to importations.

Future expansion of the herd may be made possible by two methods. One consists of increasing the rearing proportion from the present level of 0.25 to 0.33, which appears possible. Robertson and Asker *(8)* found that much of the expansion of the Friesian breed in Great Britain could be attributed to an increase in the rearing proportion from 0.26 to 0.37. They reported that in a period of constant size before 1935 the rearing proportion was 0.26 and the reproductive life about four lactations and in the period of expansion the rearing

proportion increased to 0.37 and the reproductive life to about 5.4 calvings. In the Red Sindhi herd at Polonnaruwa there is every possibility of increasing rearing proportions appreciably to facilitate herd expansion. Mortality among female calves during the 1950-53 period had been reduced to 20%, and it should therefore be possible theoretically to attain a maximum rearing proportion of about 0.38. In practice, however, this figure may not be attained because not all cows calve every year and not all calves born to Red Sindhi cows are true to type in regard to color, some being sold for that reason. The accepted color is red, the shades varying from dark red to dun yellow. The off-types are those that show white patches on the body and may comprise up to 10% of all calves born. A more likely estimate of the probable rearing proportion attainable at Polonnaruwa would then be 0.33, which means that once in about three calvings a cow may be expected to produce a heifer which survives and reaches a lactation in the herd.

The other possible method of increasing population size is to increase the average reproductive life per cow. It is generally believed that longevity is desirable because it enables the farmer to have a higher proportion of his cows at the most productive age. But the validity of this belief would depend on the economic value of longevity as compared with high yield. Nevertheless, it is clear that from the point of view of population size a longer reproductive life is desirable. The trend in average reproductive life per cow from 1938 to 1953 in the Polonnaruwa herd indicates that it should be possible to increase it to about five lactations.

Any estimate of the possible rate of expansion of a population would be dependent on the generation length. The generation length is defined as the mean age of the parents when their offspring are born and has been estimated by Lush *(2)* for temperate breeds of cattle at 4 to 4½ years. The generation lengths for the Red Sindhi herd at Polonnaruwa were found to be L_{BB} = 82 months, L_{BC} = 83 months, L_{CB} = 73 months, and L_{CC} = 73 months, where L_{BB}, L_{BC}, etc., represent the average age of the sires when the bull calves were born, the average age of the sires when the heifer calves were born, and so on. This gives a total generation length of 26 years and a mean of 6½ years, which is in close agreement with the estimates of Stonaker *(9)* for the Red Sindhi herd of the Allahabad Agricultural Institute, India, and of Mahadevan *(4)* for a herd of Sinhala cattle in Ceylon.

It may therefore be assumed that the following conditions could be achieved at Polonnaruwa:

a) The mortality rate among female calves could be kept down at the 20% level that obtained in the 1950-53 period.

b) The rearing proportion could be raised to 0.33.

c) The average reproductive life could be increased to five lactations.

d) The generation interval would be about 6 years.

On this basis, the herd at Polonnaruwa may be expected to double in size every 8 years without further resort to importations. This is a conservative

estimate; nevertheless, it shows that even in tropical breeds there is a considerable reserve of fecundity, which, if utilized properly, would permit the population to expand rapidly.

Production statistics of the herd. An interesting feature that the Red Sindhi herd at Polonnaruwa has in common with most other breeds of tropical dairy cattle is the great variation in yield. The average first lactation is about 220 gal., and the coefficient of variation is close to 40%. Robertson *(7)* reported a coefficient of variation of yield of about 50% for a herd of Fulani cattle in Nigeria, and Mahadevan *(4)* arrived at a figure of 39% for a herd of Sinhala cattle in Ceylon. The low lactation yields were almost invariably associated with short lactations. In the Polonnaruwa herd the correlation between total yield and lactation length was 0.60 ± 0.02, and that between total yield and average daily yield was 0.78 ± 0.02. Under commercial conditions in temperate countries the usual coefficient of variation of lactation yield is 20 to 22%, and the main factor governing lactation yield is the maximum daily yield, as lactations vary little in length. It would be interesting to know what obtains in temperate breeds under tropical environments.

The coefficient of variation of lactation length was 24% in the Red Sindhi herd. This agrees closely with the value of 22% reported earlier for Sinhala cattle in Ceylon *(4)*. The number of lactations ending before 200 days was 10%, and that ending before 300 days was a further 50%. It is therefore not surprising that yield was highly correlated with lactation length in this herd. It seems probable that one would get a similar picture in all relatively undeveloped dairy breeds in the tropics.

The average age at first calving at Polonnaruwa was 47 ± 0.4 months. Male calves weighed 39 ± 0.5 lb. at birth and females, 34 ± 0.6 lb. The effect of age at first calving on yield in the first lactation was small, the regression being negative and not significant. Only 10% of the heifers calved below 40 months of age, and in these the lactations were slightly higher. These results indicate that relatively early first calving is possible without any detrimental effect on first lactation production.

Sundaresan *et al. (10)* concluded that whereas in European cattle age at first calving had no significant effect on lifetime production, its effect in purebred and high-grade Indian cattle was considerable. It appears, however, from one of their tables that age at first calving showed a far greater variability in their purebred and high-grade Indian material than in the Kansas State College Jersey herd data that they studied for comparison. Whether a lowered age at first calving can be brought about by breeding is still a moot point. Stonaker's *(9)* estimate of the heritability of age at first calving of 0.39 based on 90 degrees of freedom for the purebred Red Sindhi cattle of the Allahabad Institute indicates that the age at first calving is highly heritable. Sundaresan *et al. (10)* state that whereas European cattle come in heat early and a few heat periods generally elapse before they reach the age of first breeding, Indian cattle are usually more than 36 months of age at first heat and are bred during first heat. They deduce from this that "age at first calving in European cattle is a matter

of management practices, whereas in native Indian cattle age at first calving is a consequence of age at first heat period, a physiological and probably hereditary trait." One must approach this generalization with considerable caution. Early maturity experiments conducted with other tropical breeds *(4)* indicate that it should be possible to lower the age at first calving considerably by good feeding and management in early life. Until further convincing evidence is available, the question whether early first calving in tropical cattle is largely a matter of breeding or of management must be left open.

The variation of yield with age in lactations was investigated by three methods. The first involved the averaging of the yields of all cows in a given lactation, and the results obtained by this method are depicted graphically in Curve 1, Figure 1. The second method was that of paired lactations, which yielded results represented by Curve 2. Correction terms derived from the paired lactation method tended to over-correct the records of older cows. This was to be expected as dairy records are not completely repeatable, the coefficient of intracow correlation for milk yield in this herd being 0.41. Adjustment for incomplete repeatability modified the correction terms considerably, and the age effect as derived by this method is shown by Curve 3. It will be observed that this curve approximates very closely that obtained from "lumped" data. Comparison of these results with those of previous investigators tends to confirm the view that the effect of age on yield is not independent of management. In both the Sinhala and the Red Sindhi breeds that have been investigated in Ceylon and that are subjected to very similar managerial systems peak production is attained by the fourth lactation. However, in the purebred Red Sindhis of the Allahabad Agricultural Institute herd in India, under very different conditions of management, it was found that with first records adjusted for incomplete repeatability, the first lactation remained slightly the highest *(9)*. The effect of age on yield in all these cases however, has been so small that one would not be far wrong in not using age corrections as a rule for most tropical cattle. In comparison with the figures obtained for temperate cattle, the increase in yield from first to fourth lactation was only 6% for the Red Sindhis at Polonnaruwa.

There appears to have been a slight seasonal trend in the distribution of calvings in this herd. Approximately 65% of the calvings in each lactation occurred between the months of December and June. The lower incidence of calvings from July to November may be attributed to the observed fact that both cows and bulls exhibit a marked reduction in activity during the rainy northeast monsoon period from November to February, and, in consequence, cows are less likely to conceive at this time of the year than at any other. This is further confirmed by the finding that cows conceiving during the 3 months following the cessation of the monsoon have the longest calving intervals in the herd. The variation of yield with month of calving was, however, not very marked, cows calving during the onset of the monsoon in November-December yielding just about 8% less milk than cows calving in other months of the year.

The average length of calving interval in the herd was 433 $\pm$ 4 days with a coefficient of variation of 28%. In recent years, with the considerable emphasis

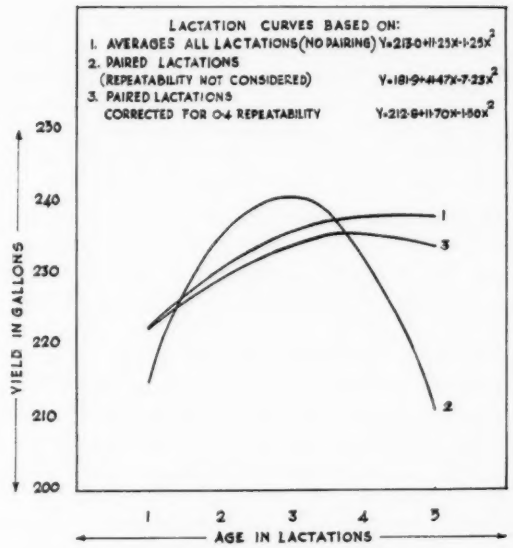

FIG. 1. Variation of milk yield with age.

that has been placed on maintaining over 70% of the cows in milk at all times, a very marked reduction has been made in the length of calving interval. The intervals for cows calving during the 1950-53 period averaged 408 days as compared with 451 days for the 1938-49 period. There has also been a corresponding reduction in the length of dry period and a slight increase in lactation length. During the years 1950-53, dry periods and lactation lengths were 116 and 292 days, respectively, as compared with 173 and 278 days for preceding years. The variation of calving intervals with age showed a strong tendency to longer calving intervals in the early lactations. The calving interval associated with the first lactation was on the average about 2 months longer than that associated with lactations at maturity. This may perhaps be partly attributed to the higher persistency of first calvers, which is evidenced by their slightly longer lactations. The regression of yield in later lactations on the length of the preceding calving interval was not significant, thereby indicating that it should be possible to decrease the length of calving interval without any detrimental effects and thus increase total lifetime production.

Analyses of the repeatability of the main components of milk production in the Red Sindhi herd at Polonnaruwa yielded the following results:

Components of milk production	*Repeatability*
Average daily yield	+0.46
Lactation length	+0.18
Calving interval	+0.15
Dry period	+0.10

Records of over 300 cows were used in arriving at each of the above estimates, so that the sampling errors were small. It will be observed that of the traits studied, the average daily yield shows the highest correlation between lactations of the same cow. The low repeatability of lactation length, calving interval, and dry period in this material indicates that selection would not be very effective in improving these characters. The high figure for average daily yield is in agreement with Robertson's *(7)* estimate of 0.5 for the repeatability of this trait in the Fulani in Nigeria. The repeatability of lactation length in the Red Sindhi is of the same order as that obtained for Sinhala cattle in Ceylon *(4)*. As regards calving interval and dry period, however, differences seem to exist between current results and previous investigations. Whereas the estimates of the repeatability of calving intervals in European cattle *(1, 3)* have all been low and not significant, Stonaker *(9)* obtained a high estimate of heritability (0.88 based on 41 degrees of freedom) for calving intervals in the Red Sindhi herd of the Allahabad Institute. It seems probable that the discrepancy shown by Stonaker's results may be due largely to high sampling errors. The low repeatability of dry periods in the present material is difficult to explain in the light of Johansson and Hansson's *(1)* finding in Swedish cattle that "the length of dry period is an individual characteristic of the cow."

The average correlation of the yield in one lactation with that in the next was found to be 0.41 in the Polonnaruwa herd. This is fairly close to the correlation of 0.46 for milk yield in Sinhala cattle in Ceylon and to the estimates of repeatability reported for butterfat yield in temperate countries. The total regression of daughters' first records on dams' first records for milk yield was 0.14 based on 91 daughter-dam pairs. The intrasire daughter-dam regressions could not be computed, as the sires used for many matings had not been recorded. But from the total regression value of 0.14 and the repeatability estimate of 0.41 it may be estimated that the heritability of milk yield in this population would probably be of the order 0.2.

No spectacular increase in milk yield has been recorded in this herd during the 16 years of its existence. The average yield in the first lactation and the average of the first two lactations of cows coming into the milking herd in the different periods are shown below:

Period	*Average 1st lact. yield (gal.)*	*Average 1st and 2nd lact. yield (gal.)*
1938-45	220	232
1946-49	222	230
1950-53	224	221

The extent of selection for milk yield actually practiced in the herd was therefore investigated. During the 1938-45 period, cows that left the herd at the end of the heifer lactation produced more milk in that lactation than those that were retained for breeding (Table 4). The over-all selection differential on first lactation for the 16 years from 1938 to 1953 was +5.4 gal. This may be

TABLE 4
Estimation of selection differential from culling practiced

Period	Selection differential on 1st lact.[a]	Genetic superiority of dams		No. of daughters in herd
		Based on 1st lact.	Based on 1st-4th lact.	
	(gal.)	*(gal.)*	*(gal.)*	
1938-41	−23.1	− 6.4	−6.1	43
1942-45	− 8.2	− 3.8	+2.6	48
1946-49	+ 4.3	+ 3.1	−4.7	62
1950-53	+ 9.9	−12.3	+2.1	9
Total	+ 5.4	− 2.5	−2.5	162

[a] Mean of 1st lactations of cows having 2nd lactations—mean of all 1st lactations.

compared with a possible selection differential of 17 to 18 gal. in a herd with the same level of production but with 25% of each year's crop of cows completing one lactation being replaced by heifers.

The estimated genetic superiority of cows weighted according to the number of their daughters that came into milk at Polonnaruwa was −2.5 gal. Table 4 shows these results according to periods. The probable genetic superiority in the period 1950-53 has been underestimated, as most of the heifers saved from cows in this group had not attained their first lactations at the time of analysis of the data and therefore could not be included. The actual selection pressure applied during this period indicates, however, that when all the surviving heifers from this period become incorporated in the milking herd, the probable genetic gain would be considerably greater. If the 1950-53 period is not taken into account, the conclusion seems inescapable that no over-all genetic progress has been made by selection of cows in the Red Sindhi herd at Polonnaruwa during the first 12 to 13 years of its existence.

No estimate was possible of the genetic improvement that may have been achieved through selection of dams of bulls, as most of the sires used until 1950 were imported from India and their ancestry was not known. It is only in recent years that home-bred sires selected on the basis of pedigree estimates have been used in this herd.

DISCUSSION

The problems associated with the breeding of dairy cattle in the tropics may be divided into two parts, those arising from climate per se and those arising from low productivity of native stock. Insofar as tropical breeds like the Red Sindhi are concerned, the problems are solely those arising from low productivity, as the necessary adaptability to the hot tropical climate is inherently present in these animals. The main components of low productivity are a late age at first calving, long calving intervals, short lactations and a low average daily yield. Any attempts to increase the productivity of native cattle in the tropics may therefore be viewed as being fundamentally concerned with some or all of these components.

To produce the desired improvement in each of these traits, it is necessary at the outset to subject each individual trait to a separate investigation in regard

to the operational wisdom of applying breeding in preference to other methods. The results obtained from the present study of Red Sindhi cattle at Polonnaruwa not only indicate the possibility of improvement of these traits in tropical cattle but also shed considerable light on the most efficient means of achieving this goal. Perhaps the most convincing evidence for the possibility of improvement is the high variability that obtains in respect to each of these traits in tropical cattle. The coefficient of variation of age at first calving for instance, is 15 to 20% for most tropical cattle as compared with about 10% for temperate zone cattle. Coefficients of variation of calving intervals, lactation lengths, average daily yields, and total lactation yields are also considerably higher in tropical cattle, being approximately 28%, 24%, 27%, and 40%, respectively, in the present material. With coefficients of variation of this order it is undoubted that the progress possible would be high, provided the most efficient means of achieving the desired end are adopted.

The repeatability estimates presented in this paper indicate that whereas the improvement of some of these traits is largely a matter of better feeding and management, in others sufficient genetic variation may still exist after optimum nonhereditary conditions have been established to warrant the application of breeding methods of improvement. Age at first calving, length of calving interval, and length of lactation may be regarded as belonging to the first category, though Stonaker's *(9)* high estimates of heritability for the first two of these traits may shed some doubt on this point. But the rapid progress that has been achieved by better management techniques in lowering the length of calving interval in the Polonnaruwa herd and the results of early maturity experiments to lower the age at first calving in other tropical cattle strongly support the conclusion drawn from the low repeatability figures that much improvement in these traits could be achieved by better feeding and management.

Average daily yield and total lactation yield, however, are moderately repeatable (0.46 and 0.41, respectively), with total lactation yield having a heritability of about 0.2. Selection would therefore be a useful tool in improving these characters. One might then ask to what extent selection for these characters has actually been practiced in this herd. The estimates that have been presented of the genetic superiority of dams of cows over their contemporaries show that the intensity of selection applied leaves much to be desired. As, in fact, the effective breeding period in this herd since its inception has been about 13 years, one would expect the genetic improvement to have been at least of the order of 20 to 30 gal. in lactation yield. But what has really been achieved is an over-all negative selection pressure for yield.

The main generalization that can therefore be made from the study of the production statistics of this herd is that there is considerable variability within most breeds of tropical cattle to permit a reasonably rapid advance in productivity. Apart from the employment of better and more uniform techniques of feeding and management, the maintenance of low mortality rates, adequate rearing proportions, and short generation intervals will also help very considerably in raising productivity. The importance of the latter aspects has already

been discussed in relation to possible future expansion of the Polonnaruwa herd. It may nevertheless be emphasized here that lower mortality rates, higher rearing proportions, and shorter generation intervals, besides making rapid herd expansion possible, also allow a greater selection pressure to be applied. This would accelerate the annual genetic improvement of stock.

SUMMARY

The mechanism of population changes in the 16-year history of a large herd of Red Sindhi cattle in Ceylon indicates that there is a considerable reserve of fecundity in these animals that could be utilized to enable the population to double itself, if necessary, every 8 years. This would involve increasing the rearing proportion to 0.33 and the average reproductive life to five lactations and keeping down mortality rates at 20%. The prevailing generation interval is about 6 years.

Analyses of the production statistics of the herd show that sufficient variability exists in regard to most characters affecting milk production to warrant the possibility of a reasonably rapid advance in production in future years. Such improvement appears possible in the following directions: reduction of age at first calving, shortening of calving intervals and dry periods, and increase of lactation lengths. The coefficients of variation of total milk yield and average daily milk yield too are large enough to permit rapid improvement.

Estimates of genetic changes in the herd through selection of breeding females have also been made. The various factors that would enable a greater selection pressure to be applied for accelerating annual genetic improvement in milk yield in tropical cattle are discussed.

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THE NUTRITIONAL MERITS OF PELLETING CALF STARTERS[1]

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Since the feed pelleting process was first introduced into this country in 1929, it has gained tremendous popularity among feed manufacturers. Based on a study of feeds manufactured by 14 cooperative feed mills, Rickey *(7)* found in 1951 that the output of pelleted feeds varied from 10 to 85% of the total output.

Among the advantages found for pelleting swine *(3)* and poultry *(2, 4)* feeds are improved feed efficiency through reduced wastage, increased palatability, and greater feed intake than for unpelleted feeds. Ohio workers *(1)* in 1939 and Newman and Savage *(6)* in 1938 found that young dairy calves fed starter rations partially pelleted grew at slightly slower rates than calves fed unpelleted starters. In the latter study the pelleted rations were less palatable to calves from 2 to 6 weeks of age.

This study was conducted to determine the nutritional values of pelleting calf starters. A large percentage of the calf starters sold in Kentucky is prepared in an all-pellet or partial-pellet form.

EXPERIMENTAL PROCEDURE

This study was conducted in two phases. In the first, 39 2-day-old calves were used. The calves were divided into three comparable groups (7 Holstein and 6 Jersey) and fed one of three experimental calf starters identical in composition, varying only in physical texture. These starters were composed of 225 lb. linseed oil meal, 540 lb. crimped oats, 260 lb. ground yellow corn, 225 lb. wheat bran, 450 lb. distillers dried solubles, 22.5 lb. each of bone meal and iodized salt, 900 g. of a vitamin A and D supplement,[2] and 12.2 lb. of Aurofac 2A. Starter 1 was prepared in the meal form; Starter 2 was pelleted, giving a pellet 3/16 in. in diameter, and Starter 3 was part meal and part pellet. All of the ingredients except the wheat bran and crimped oats were pelleted in Starter 3. These two ingredients were mixed with the pellets after the pelleting process in the same proportion as in the other starters. The chemical composition of these starters was as follows: dry matter, 90.9%; crude protein, 17.9%; ether extract, 5.8%; crude fiber, 6.7%; ash, 7.1%; nitrogen-free extract, 53.4%.

The calves were fed a limited amount of whole milk, according to a milk feeding schedule previously described *(5)*. All starters and good quality alfalfa hay were fed free-choice starting at 1 week of age. The calves were weighed

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[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

[2] Vitamin A and D supplement contained 10,000 I.U. of vitamin A and 500 I.U. of vitamin D per gram.

when 2 days old and at weekly intervals until they were 72 days old. Body measurements, height at withers, and chest circumference were taken at monthly intervals. Daily observations were made as to the condition of the calves and the incidence of scours. Complete records were kept on the consumption of milk, starter, and hay.

In the second phase, six 2-day-old calves were used. The calves were managed exactly as in the first phase except that each of the six calves was offered all three starters. The position of the starters in the compartment-type feed boxes was changed twice weekly.

RESULTS AND DISCUSSION

Data presented in Table 1 indicate that the physical state of the calf starters had very little effect on the growth rate or the incidence of scours. The average daily gain of the calves fed the all-pellet starter (Starter 2) was slightly greater than that of the calves fed the two other starters, but this difference was not

TABLE 1

Effect of pelleting calf starters upon the daily rate of gain, skeletal growth and the incidence of scours in young dairy calves to 72 days of age

Group	Av. initial wt.	Av. daily gain	Av. increase in		Incidence of scours
			Ht. at withers	Heart girth	
	(lb.)	*(lb.)*	*(in.)*	*(in.)*	*(days/calf)*
1 (Meal) Starter 1	76.4	0.92	3.65	5.77	1.38
2 (Pellets) Starter 2	74.6	0.96	4.02	6.77	0.85
3 (Meal plus pellets) Starter 3	74.8	0.92	4.19	6.23	1.54

statistically significant *(8)*. Similar results were observed as to the effect of the various starters on skeletal growth. These results are contrary to the findings of the Ohio workers *(1)* and Newman and Savage *(6)*, who observed that calves fed pelleted rations gained in weight at a slower rate than calves fed unpelleted rations. The incidence of scours in this experiment was relatively low; therefore, the small differences that existed are not considered significant.

The effect of the physical texture of the calf starters on feed consumption and feed utilization is shown in Table 2. These data show that the consumption of the all-pellet starter was slightly higher than that of either the meal or the

TABLE 2

Effect of pelleting calf starters upon feed consumption and efficiency of feed utilization

Group	Average total consumption			Feed/gain
	Milk	Starter	Hay	
	(lb.)	*(lb.)*	*(lb.)*	*(lb/lb)*
1 (Meal)	221.2	83.0	40.6	2.35
2 (Pellets)	209.0	89.2	42.2	2.33
3 (Meal plus pellets)	216.4	81.6	43.2	2.35

TABLE 3
Starter and hay consumption as affected by age of calf (pounds of starter or hay/period)

Group	Starter				Hay			
	Weeks				Weeks			
	1-4	1-6	5-10	7-10	1-4	1-6	5-10	7-10
1 (Meal)	3.7	14.5	79.3	68.5	1.8	9.1	38.8	31.5
2 (Pellets)	3.8	16.6	85.4	72.6	2.3	9.5	39.9	32.7
3 (Meal plus pellets)	2.7	13.3	78.9	68.3	2.2	9.2	41.0	34.0

meal plus pellet starter. However, these differences are not statistically significant. There was very little difference in the consumption of hay or feed required to produce a pound of gain among the three groups of calves. The data in Table 3 showing the consumption of feed as affected by the age of the calf indicate the relative palatability of the various starters during the early life of the calves. There were some indications that Starters 1 and 2 were slightly more palatable than Starter 3 when the calves were less than 4 weeks of age. Starter 2 appeared to be slightly more palatable than Starters 1 and 3 during the 1 to 6, 5 to 10, and 7 to 10-week-old period. There was very little difference in the consumption of hay by the various groups during any age period. The feed consumption data obtained in this experiment show that the pelleting of calf starters does not reduce the palatability of these feeds.

A summary of the starter consumption data obtained in the second phase of this study is presented in Table 4. In this phase of the experiment six calves were permitted to consume unlimited quantities of all starters. When the palatability of the various starters was tested in this manner, a decided difference in the consumption of the starters existed. The consumption of the all-pellet starter was significantly higher ($P < 0.01$) than that of either of the two other starters. The consumption of Starter 3 was significantly greater than that of Starter 1. The improved palatability of starters containing pellets was evident during nearly all age periods.

The results of this experiment show that, when the calves have a choice among the three types of starters, those prepared in either an all-pellet or part-pellet form are more palatable than a starter prepared in the meal form. However, the palatability of all starters appeared to be equal when the calves were limited to one type. Under such conditions all three starters promoted comparable

TABLE 4
Consumption of the various starters when the calves were offered all three starters free-choice

Starter	Av. total consumption	Weeks			
		1-4	1-6	5-10	7-10
	(lb.)	*(lb/period)*			
1 (Meal)	21.1	2.6	6.8	18.5	14.3
2 (Pellets)	56.2	2.9	11.2	53.3	45.0
3 (Meal plus pellets)	43.4	4.3	10.1	39.1	33.3

growth of the calves from birth to 12 weeks old. It should be mentioned that the results in this experiment were obtained with only one basal calf starter and the results might have been different if different ingredients had been used in the basal starter. There are possibly reasons other than those considered in this experiment for the pelleting of calf feeds by feed manufacturers. In this study there appeared to be no nutritional advantages of pelleting calf starters.

SUMMARY

Forty-five new-born dairy calves were raised to 72 days of age on a limited milk-hay-starter system to study the nutritional merits of pelleting a calf starter. The starters were prepared in three forms: all meal, all pellet, and part meal and part pellet.

When the calves were limited to just one type of starter, it was found that the physical texture of the starters had no significant effect on the average daily gain, skeletal growth, incidence of scours, the consumption of hay or starter, or the efficiency of feed utilization of the calves. However, the calves consumed slightly more of the starters that were pelleted than of the other starter.

When the calves could choose any one of the three starters, they consumed significantly more of the all-pelleted starter than either of the two other starters. Also, the consumption of the part-meal and part-pellet starter was significantly greater than that of the all-meal starter. Under the conditions of this experiment no nutritional advantages were found for the pelleting of calf starters.

ACKNOWLEDGMENTS

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COMPARISON OF ALFALFA HAY AND ALFALFA SILAGE AS ROUGHAGE FOR GROWING DAIRY HEIFERS IN A LIMITED MILK AND GRAIN FEEDING SYSTEM

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Several investigators have shown that satisfactory growth of dairy heifers may be obtained when hay, hay and pasture, or hay and corn silage are the only feeds provided from 6 to 24 or 12 to 24 months of age *(4, 5, 11)*. Converse *(3)* also has shown that dairy heifers make satisfactory growth when alfalfa hay, alone or combined with other hays or corn silage, was the only feed fed from 8 or 9 to 24 months of age. In that work milk feeding was discontinued at 60 days of age and grain feeding at 8 or 9 months of age. Grain feeding was also limited to the extent that a total of about 560 lb. per heifer was fed from birth to 8 or 9 months of age. With the exception of the feeds fed in the Oregon study *(11)*, these are the smallest recorded quantities of milk and grain that have been fed in high roughage rations for rearing dairy heifers to 24 months of age.

The relative value of hay crop silages as compared to hay or hay and corn silage rations is of interest because of the present trend toward making a larger portion of the hay crop into silage and because of the smaller acreage of corn now being grown for silage. Wilson and Bartle *(12)* have shown that yearling heifers made less gain in both weight and skeletal growth when they were wintered on alfalfa silage as compared to alfalfa hay. Bender *(1)* noted that yearling heifers maintained on grass silage and limited hay made subnormal gains, as judged by the Ragsdale standard. Hodgson *et al. (5)* also have noted that heifers maintained during the winter on hay crop silages and mixed hay did not gain as well as heifers maintained on high quality alfalfa hay and corn silage. Keener *et al. (7)*, however, during a 7-week feeding period, obtained considerably greater gains from silage than from hays of the same crop, and Porter and Kesler *(9)* have shown that no significant differences occurred in growth rate of calves fed hay, hay silage, or a combination of these feeds as the only roughage to 16 weeks of age. When these roughages were fed with a maximum of 5.0 lb. of calf starter daily, growth rates were greater than when starter was limited to 2.0 lb. daily, in spite of increased roughage intake in the latter groups.

The present work is a comparison of the results obtained when alfalfa silage or alfalfa silage and a limited amount of alfalfa hay replaced alfalfa hay as forage for growing dairy heifers under similar limited milk and grain feeding conditions as have been used in previous work *(3)* from this laboratory.

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EXPERIMENTAL PROCEDURE

Nineteen Holstein and 47 Jersey heifers were assigned to these experiments at random as they were born in the herd. Because of losses from various causes only 35 Jersey heifers remained in the experiment for 24 months or more. Three main groups were set up on the basis of the type of forage fed. Group 1 was fed alfalfa hay as the only forage, Group 2 was fed wilted alfalfa silage and limited quantities of alfalfa hay, and Group 3 was fed wilted alfalfa silage. Within Group 2 there were three subgroups, which varied in the quantity of hay fed with the alfalfa silage. Group 2A was fed hay at the rate of ½ lb. per 100 lb. of body weight per day, Group 2B was fed hay ad libitum for 180 days and at the rate of ½ lb. per 100 lb. of body weight thereafter, and Group 2C was fed hay ad libitum for 180 days and silage only thereafter. Since there were no statistically significant differences in growth rate between these three subgroups, they are discussed as one group (Group 2).

The silage fed was wilted alfalfa with no preservative added. The average dry matter content of the silage fed was 33%. First, second, and third cutting alfalfa from stands with relatively little grass and a minimum of foreign matter, with some minor exceptions, was used. The alfalfa was cut when about one-third of the crop was in bloom. Silage from five consecutive crop years was fed during the experiment and every effort possible was made to ensure uniform high quality insofar as this was possible. Most of the hay used was purchased U. S. No. 1 Alfalfa or U. S. No. 2 Leafy, 45% Green Alfalfa. Some home grown alfalfa of the same crop which provided silage was also fed when it was available. This hay was of a quality equivalent to the purchased hay. The hay fed was purchased or made during five consecutive crop years and, as far as can be judged by U. S. grades, was of reasonably uniform good quality. Within the limitations imposed by the usual criteria for judging quality of hay or silage, both the hay and silage fed were of good quality at all times. The appropriate forage was offered to the calves at 10 days of age and was increased according to appetite. A daily weighback of one or more pounds was maintained except when hay was fed according to body weight.

All calves were fed colostrum for 3 days after birth and whole milk until 60 days of age. No skimmilk or milk substitute was fed. The amounts of milk fed per day were as follows:

Age *(days)*	Jersey *(lb.)*	Holstein *(lb.)*
0-10	6.0	8.0
10-20	7.0	9.0
20-30	8.0	8.0
30-40	7.0	6.0
40-50	5.0	4.0
50-60	4.0	2.0

Concentrate was offered at 10 days of age and was increased according to appetite until 3.0 lb. per day were being consumed. It was maintained at this

level until the calves were 150 days of age, when it was reduced to 2.0 lb. daily. This amount was fed until they were 240 days of age, when grain feeding was discontinued. No grain was fed from 240 days until after calving. The concentrate mixture was composed of the following ingredients: corn meal, 300 lb.; linseed oil meal, 250 lb.; soybean oil meal, 250 lb.; wheat bran, 200 lb.; salt, 10 lb. This grain feeding schedule was not always strictly adhered to. A few heifers in Groups 1 and 2 were fed smaller quantities of grain—generally by restricting the rate of increase in grain fed or by feeding grain for less than 8 months. Salt was available during the time the heifers were in the exercise lot. The experiment was conducted under dry lot conditions at all times.

The experimental period extended from birth to 24 months of age. All heifers were bred starting at 16 months of age. They were fed individually, and detailed records of feed consumed or refused were kept. The feeds were analyzed periodically for proximate constituents. Body weight was determined on three consecutive days at 30-day intervals. In addition, single day weights were taken at 10-day intervals during the first year of the calf's life.

The data from this experiment were subjected to an analysis of variance, and tests of significance were determined for appropriate comparisons.

RESULTS AND DISCUSSION

The body weight changes of these heifers from birth to 24 months of age are presented in Figure 1. For comparative purposes, curves representing the Ragsdale standard *(10)* are included.

Satisfactory rates of growth were obtained with both Holstein and Jersey heifers when hay was the only roughage fed (Group 1) in spite of the fact that these heifers were fed less concentrate to 8 months of age than the heifers in previous work *(3)*. The Holstein heifers exceeded the Ragsdale standard. The Jersey heifers were somewhat below the Ragsdale standard for most of the growth period but equaled this standard at 2 years of age.

The growth rate of the heifers which were fed silage as the only forage (Group 3) was distinctly less than that of the heifers fed all hay. The average weight at 2 years of age for the Group 3 heifers was 646 and 911 lb. for Jerseys and Holsteins, respectively, whereas comparable weights for the Group 1 heifers were 737 and 1,151 lb. The differences in body weight of these two groups of heifers were significant at the 1% level both at 12 and at 24 months of age.

When limited quantities of hay were fed with alfalfa silage (Group 2), growth rates were improved but still were less satisfactory than when alfalfa hay was the only forage fed. When the calves were 2 years of age, the average body weight of the Holstein heifers in this group was significantly greater ($P < 0.01$) than that of the Group 3 heifers and less than that of the Group 1 heifers. The differences in body weight between these groups were also significant ($P < 0.05$) at 1 year of age. The average body weight of the Jersey heifers in Group 2 was significantly less ($P < 0.01$) than that of the Group 1 heifers at 1 year of age and approached significance ($P < 0.05$) at 2 years of age. The

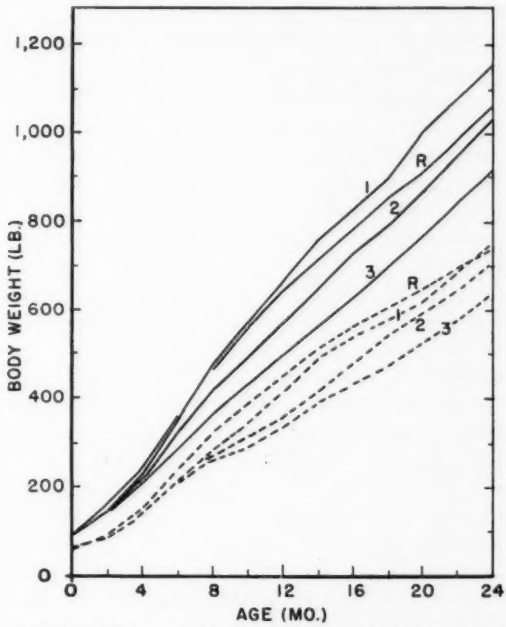

FIG. 1. Growth rate of Holstein and Jersey heifers on alfalfa hay and wilted alfalfa silage rations. Solid lines = Holstein heifers, broken lines = Jersey heifers, R = Ragsdale standard, 1 = Group 1 heifers (alfalfa hay), 2 = Group 2 heifers (alfalfa silage and limited hay), 3 = Group 3 heifers (alfalfa silage).

Group 2 Jerseys were significantly heavier ($P < 0.05$) than the Group 3 Jerseys at 2 years of age but not at 1 year.

As noted previously, the amount and manner of feeding hay to the heifers in Group 2 was variable. In no instance were the differences in growth rate between these subgroups significant. This is particularly surprising of Group 2C heifers, which were maintained on silage alone from 6 to 24 months of age. The growth rate of these heifers might have been expected to approximate more closely that of the Group 3 heifers. Evidently the 2C heifers had developed sufficient capacity for roughage during the 6 months they were fed hay and silage to enable them to consume sufficient silage from 6 to 24 months of age so that body weight gains were equal to the 2A and 2B heifers, which were fed hay and silage continuously.

It will be noted (Figure 1) that the differences in growth rate between Groups 1, 2, and 3 were most evident from 5 to 12 months of age. At 5 months of age there were small but evident differences in the average body weight between groups. The differences were more marked at 8 and 12 months of age. After 12 months of age the average gain in weight was very similar between groups, as shown in Table 1. The only statistically significant difference occurred between the Jersey Groups 2 and 3.

TABLE 1
Average gain in body weight from 12 to 24 months of age

	Weight at 12 months	Weight at 24 months	Gain
	(lb.)	*(lb.)*	*(lb.)*
Jersey			
Group 1	417	737	320
Group 2	360	703	343
Group 3	338	646	308
Holstein			
Group 1	670	1151	481
Group 2	554	1039	485
Group 3	486	911	426

Other investigators *(1, 5, 12)* have not observed as marked a difference in growth rate when hay was compared to hay silage as has been observed in the present study. However, the above workers used yearling heifers and the growth rate of their heifers was more comparable to the growth rates of the heifers in the present experiment during a comparable age period. These observations suggest that satisfactory growth may be obtained when hay crop silage is fed as the only forage to yearling heifers, provided they have maintained reasonably normal rates of gain during the first year. The results of the present work indicate that, in the limited milk and grain feeding system which has been used in this experiment, alfalfa silage will not maintain normal growth rates, particularly during the first year. The optimal amounts of hay, other forages, or grain which must be fed with alfalfa silage to maintain normal growth have not been determined. Experiments to determine these are in progress and will be reported subsequently.

Feed consumption data for these heifers are presented in Table 2. The average total grain consumption of the Holstein heifers was 459, 475, and 496 lb.

TABLE 2
Average feed consumption per heifer

Period	Holstein				Jersey			
	Milk[a]	Grain[b]	Hay	Silage	Milk[a]	Grain[b]	Hay	Silage
	(lb.)	*(lb.)*	*(lb.)*	*(lb.)*	*(lb.)*	*(lb.)*	*(lb.)*	*(lb.)*
			Group 1					
Birth to 12 mo.	360	459	3,479	—	366	356	2,169	—
12 to 24 mo.	—	—	8,728	—	—	—	5,675	—
			Group 2					
Birth to 12 mo.	353	476	391	6,531	360	379	334	3,606
12 to 24 mo.	—	—	841	14,785	—	—	533	11,045
			Group 3					
Birth to 12 mo.	362	496	—	6,324	364	400	—	4,133
12 to 24 mo.	—	—	—	14,283	—	—	—	10,970

[a] Discontinued after 60 days.
[b] Discontinued after 240 days.

for Groups 1, 2, and 3, respectively. These are smaller quantities of grain than was fed in the previous work *(3)*. Within Group 1, four of the heifers consumed an average of 514 lb. of concentrate; the average grain consumption of the three remaining heifers was 387 lb. Although the growth rate of the heifers on the higher grain level was rather consistently above that of the heifers on the lower level in Group 1, the difference was not statistically significant, and both lots exceeded the Ragsdale standard. These data suggest that no more than about 400 lb. of grain need be fed during the first 8 months of age to Holstein heifers for normal growth when high quality alfalfa hay is fed as the only forage.

The average grain consumption of the Jersey heifers was 356, 379, and 400 lb. for Groups 1, 2, and 3, respectively. Within Group 1, six heifers consumed an average of 404 lb. of grain; four other heifers consumed an average of 280 lb. of grain. As was true of the Holstein heifers, those on the higher grain level made greater gains than the heifers fed the lower quantity of grain, although the difference was not statistically significant. The heifers on the higher level equaled or exceeded the Ragsdale standard from 21 to 24 months of age but were somewhat below it from birth to 21 months of age, whereas the Holstein heifers generally exceeded the Ragsdale standard. This observation indicates that 400 lb. is the minimum quantity of grain that should be fed to Jersey heifers to enable them to attain normal size at 2 years of age when high quality alfalfa hay is the only forage fed. When these results are considered in the light of previous work *(3)*, a grain allowance of about 500 lb. during the first 8 months of age would appear to be adequate for Jersey heifers in this type of feeding regime.

The consumption of total digestible nutrients by the heifers in the three groups has been calculated and is presented in Figures 2 and 3 for Holsteins and Jerseys, respectively. Curves representing the National Research Council allowance *(8)* for heifers making gains equivalent to the Ragsdale standard *(10)* are included for comparative purposes.

The growth rate of the heifers in the groups paralleled TDN intake. The Holstein heifers in Group 1 consumed more TDN than was required to meet the NRC allowance and exceeded the Ragsdale standard in growth, whereas the Jersey heifers in this group consumed less than was required and were generally slightly below the Ragsdale standard in growth. The feed intake of the heifers in Groups 2 and 3, which were fed alfalfa silage and limited hay or alfalfa silage only as roughage, was distinctly lower than the NRC recommended allowance. As previously noted, growth rates were significantly less than in Group 1, and the difference in growth rate between Groups 2 and 3 is a direct reflection of the difference in feed intake.

The TDN consumption per 100 lb. of body weight has also been calculated. These data are shown in Table 3. Feed consumption per unit of body weight was generally less in Groups 2 and 3 than in Group 1. This difference was not evident until after the calves were 5 months of age except in the Group 3 Holstein heifers. Grain consumption was reduced from 3.0 to 2.0 lb. daily at this time. The combined grain and forage allowances up to 5 months of age were apparently

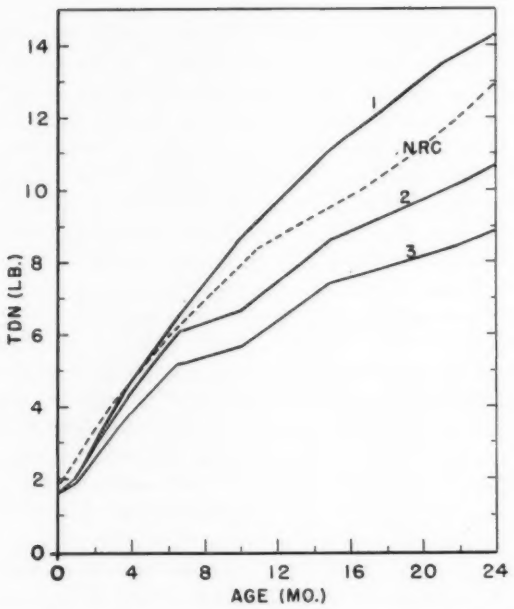

FIG. 2. Average daily consumption of total digestible nutrients by Holstein heifers. NRC = National Research Council recommended allowances, 1 = Group 1 heifers (alfalfa hay), 2 = Group 2 heifers (alfalfa silage + limited hay), 3 = Group 3 heifers (alfalfa silage).

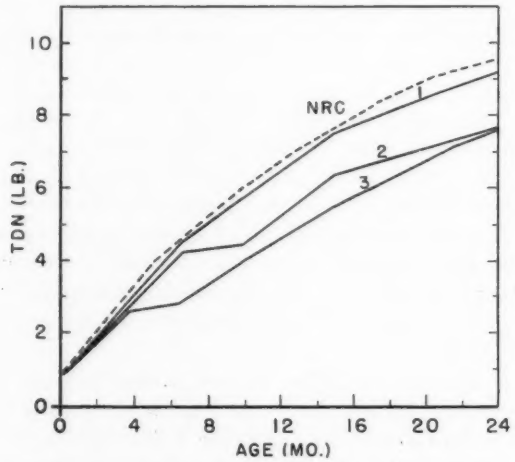

FIG. 3. Average daily consumption of total digestible nutrients by Jersey heifers. NRC = National Research Council recommended allowances, 1 = Group 1 heifers (alfalfa hay), 2 = Group 2 heifers (alfalfa silage + limited hay), 3 = Group 3 heifers (alfalfa silage).

TABLE 3

Average TDN consumption per 100 lb. of body weight per day by periods

Period	Group 1	Group 2	Group 3
	(lb.)	*(lb.)*	*(lb.)*
	Holsteins		
0-2 mo.	1.72	1.75	1.52
2-5 mo.	1.97	1.99	1.85
5-8 mo.	1.71	1.73	1.66
8-12 mo.	1.52	1.37	1.33
12-18 mo.	1.41	1.30	1.28
18-24 mo.	1.32	1.11	1.06
	Jerseys		
0-2 mo.	2.07	2.00	2.02
2-5 mo.	2.05	1.98	1.98
5-8 mo.	1.98	1.89	1.2..
8-12 mo.	1.63	1.39	1.32
12-18 mo.	1.50	1.40	1.33
18-24 mo.	1.30	1.14	1.23

sufficient to maintain fairly normal feed intakes and growth rates during this period, although both feed intake and growth were slightly less in Groups 2 and 3 than in Group 1. From 5 to 24 months of age, when alfalfa silage provided the only or major source of nutrients in Groups 2 and 3, TDN consumption per unit of weight was distinctly less than in Group 1, although the difference was not as great as might have been expected from the differences in growth rate between groups. It will also be noted that the TDN intake per 100 lb. of body weight tended to be greater for the Jersey heifers than for the Holsteins at comparable ages.

These observations suggest that the reduced feed intake observed in Groups 2 and 3 was not so much the result of lack of capacity to consume enough silage to meet requirements as a lack of appetite for alfalfa silage. It would also be expected that, if capacity were a limiting factor on adequate intake of silages, a more severe limitation would occur when cattle are on pasture or are fed freshly clipped pastures. Ittner *et al. (6)* have recently observed that beef steers that were pastured or fed on green clipped alfalfa plus small quantities of oat hay gained 1.92 lb. per day during a 168-day feeding period. In the present experiment the average daily gain of the heifers in Groups 2 and 3 from 12 to 18 months of age was 0.83 and 1.18 lb. per day for Jerseys and Holsteins, respectively. The alfalfa silage fed to these heifers had a higher dry matter content (average 33%) than the fresh clipped forage (average 25%) fed by Ittner *et al.*

The amount of TDN consumed per pound of gain was slightly less for the heifers fed the alfalfa silage rations (Groups 2 and 3) than it was for the hay-fed heifers (Group 1) when the whole experimental period was considered. During the first 12 months there was little or no difference in efficiency of utilization, even though marked differences in growth rate occurred. During the second 12 months, however, when all groups made about equal gains in weight (Table

1), the amount of TDN consumed per pound of gain was consistently less when alfalfa silage or alfalfa silage and limited hay were the only source of nutrients. These data are shown in Table 4.

This apparent increased efficiency of utilization of nutrients from alfalfa silage as compared to alfalfa hay appears contradictory in view of the fact that over-all development was markedly retarded in the heifers on these silage rations. This result, therefore, may be an artifact and is possibly a result of the fact that the stage of growth and types of metabolic activity were not strictly comparable among the groups. The difference was still evident even when allowance was made for the varying maintenance requirement. The heifers fed hay (Group 1) were in good physical shape throughout and were well fleshed at 24 months of age. The heifers in Groups 2 and 3 were in much poorer condition throughout and were thin at 24 months of age. These heifers did not attain mature size even at 24 months of age although they grew throughout. The hay-fed heifers not only attained mature size but, particularly during the second year when the rate of growth was slowed down, also accumulated more fat. This difference between these groups in the type of gain made during the second year is a possible explanation for the apparent increased efficiency of feed utilization by the heifers fed silage. A comparison of the total body energy accumulated would possibly be a fairer basis on which to calculate efficiency of utilization in these groups of heifers.

Except for the unthrifty appearance of the heifers in Groups 2 and 3, the health of the heifers in all groups was generally good. Twenty-two animals were assigned to Group 1. Three animals were lost as the result of scours—all before 60 days of age. Fifteen were treated for varying degrees of scouring. One heifer died of unknown causes at 150 days of age and another was discarded at 300 days of age. One heifer aborted at 23 months. The average age at calving of the remaining heifers was 27.8 months. Thirty-three heifers were assigned to Group 2. Five were lost because of scours before 60 days of age out of a total of 26 which were treated for scours. Two heifers were discarded for reasons of sterility and one aborted at 27 months of age. The average age at calving was 26.1 months. Eleven heifers were assigned to Group 3. Two animals died from

TABLE 4

Total digestible nutrients consumed per pound of gain

Period	Group 1		Group 2		Group 3	
	Holstein	Jersey	Holstein	Jersey	Holstein	Jersey
	(lb.)	*(lb.)*	*(lb.)*	*(lb.)*	*(lb.)*	*(lb.)*
0-2 mo.	2.16	2.72	2.29	2.43	2.26	2.62
2-5 mo.	2.51	2.61	2.67	2.70	2.81	2.65
5-8 mo.	3.62	4.09	3.99	3.95	4.45	4.03
8-12 mo.	5.38	5.29	6.20	6.00	5.71	6.79
12-18 mo.	8.63	8.67	6.83	6.53	6.87	7.57
18-24 mo.	10.10	9.60	7.31	7.76	6.88	7.11
0-12 mo.	3.79	4.02	4.03	4.03	4.52	4.14
12-24 mo.	9.41	9.15	7.08	7.14	6.88	7.30
0-24 mo.	6.33	6.43	5.59	5.67	5.75	5.78

scours out of nine which were treated. One heifer was discarded as being sterile. The average age at calving was 27.7 months. It is evident from these data that losses from scours were not affected by the different rations. A higher percentage of animals was treated for scours in Groups 2 and 3. This is probably a reflection of the fact that the consistency of the feces tended to be more fluid in these heifers than in Group 1. Heifers were treated for scours, usually with sulfathiazole, whenever the consistency of the feces was excessively fluid. No difference in reproductive performance was noted between groups in spite of the unthrifty condition of the heifers in Groups 2 and 3, and the over-all reproductive performance was within the normal range.

The bacterial flora of three yearling heifers which were being fed alfalfa silage only was determined and compared to the flora of mature cows on a ration of alfalfa hay. Marked similarities in the ruminal flora of the two lots of animals were found *(2)*. The unthrifty appearance and slow growth rates of the silage-fed heifers, therefore, could not be accounted for on the basis of differences in the rumen flora.

SUMMARY AND CONCLUSIONS

This experiment has demonstrated again that satisfactory growth can be obtained in dairy heifers in a limited milk and grain feeding system when high quality alfalfa hay is the only forage fed. The data indicate that a total concentrate consumption of 400 lb. for Holstein and 500 lb. for Jersey heifers from birth to 8 months of age is adequate in this type of ration. No concentrates were fed from 8 months of age to calving, alfalfa hay providing the only source of nutrients.

Markedly subnormal rates of growth resulted when good quality wilted alfalfa silage to which no preservatives were added replaced alfalfa hay as a source of nutrients in a similar feeding system. When a strictly limited amount of alfalfa hay was fed with the alfalfa silage in this system, some improvement in growth rate occurred but it was still distinctly below normal.

Dairy heifers did not consume sufficient nutrients to make normal gains in body weight from birth to 24 months of age when alfalfa silage or alfalfa silage and limited hay were the only forages fed. It is suggested that this was due not so much to insufficient capacity as to a lack of appetite for alfalfa silage. This effect is most pronounced during the first 12 months of age.

It is apparent that alfalfa silage is unsatisfactory as the only roughage for growing dairy heifers in this limited milk and grain feeding system, although these data should not be interpreted as an indication that alfalfa silage cannot be used as a feed for growing dairy heifers under other conditions. In order to utilize alfalfa silage in rations for dairy heifers it appears that other forages or larger quantities of concentrate than have been used in the present work must be fed in addition to alfalfa silage. The amounts of these other feeds which must be used have not been determined. There is a suggestion, however, in the present data, as well as in the work of others, that alfalfa silage could be used as a sole source of nutrients for heifers over 1 year of age.

In spite of the very unthrifty appearance and reduced rate of growth of heifers fed alfalfa silage, the feeding of this forage had no apparent effect on losses from scours or on the reproductive performance.

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ANTIBIOTICS IN DAIRY CATTLE NUTRITION. V. COMPARATIVE EFFECTS OF STREPTOMYCIN AND AUREOMYCIN[1] ON THE GROWTH AND WELL-BEING OF YOUNG DAIRY CALVES[2]

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Reid *et al. (11)* recently reviewed the results of experiments pertaining to the feeding of antibiotics to ruminants. It is apparent that there is a paucity of information on the effects of feeding streptomycin to calves. Williams and Knodt *(13)* supplemented a basal milk replacement ration with an animal protein factor supplement that "contained some streptomycin." The growth response from this supplement was not greater than the response from the basal ration.

Streptomycin has been shown to be effective in the treatment of certain types of scours *(5, 6, 7, 9, 12)*. It has also been reported to have growth-promoting properties when fed to swine and poultry. Therefore, it seemed desirable to determine its value as a growth promoting substance for dairy calves. Aureomycin has been studied extensively for calves and its growth promoting and disease controlling properties are well established *(11)*. Therefore, in this experiment not only were the calves fed streptomycin compared with control calves, which received no antibiotic supplement, but in addition, a further estimate of the value of feeding streptomycin was obtained by comparing the streptomycin-fed calves with a similar group of calves fed aureomycin.

EXPERIMENTAL PROCEDURE

Thirty-six Ayrshire, Guernsey, Holstein, and Jersey calves were used. Because the calves differed as to sex, breed, and time of birth, a balanced incomplete block design—plan 11.1, Cochran and Cox (*1*, p. 329) re-randomized three times—was employed. Two calves of the same breed and sex were successively assigned, according to order of birth, to each block. Four treatments were compared with nine calves in each treatment group. The antibiotic treatments were: Group I, no antibiotic; Group II, 30 mg. crystalline aureomycin hydrochloride (Lederle); Group III, 30 mg. streptomycin sulfate (Merck); and Group IV, 90 mg. streptomycin sulfate. All feeding levels of antibiotics are reported on a 100-lb. body weight basis. The antibiotics were administered orally once daily by capsule commencing at birth.

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[1] The trademark of Lederle Laboratories Division, American Cyanamid Co., Pearl River, N. Y., for the antibiotic chlortetracycline.

[2] Contribution No. 235, Department of Dairy Husbandry, and No. 19, Statistical Laboratory, Kansas Agricultural Experiment Station, Manhattan. Supported in part by a grant from Merck and Co., Rahway, N. J.

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All calves were born in the Kansas State College dairy herd. They were started on experiment at birth and continued until 16 weeks old. The calves remained with their dams during their first day and then were placed in individual pens until the experiment was terminated. All calves received their mothers' colostrum the first 3 days. Beginning with the fourth day they were fed whole milk at approximately 10% of body weight daily for the next 4 weeks. After the fourth week, the rate of milk feeding was gradually reduced until a total of 350 lb. had been consumed. The calves usually were weaned between 6 and 8 weeks of age.

Good quality alfalfa hay and a calf starter were fed ad libitum beginning at 1 week of age. The starter was calculated to contain 18% digestible protein and consisted of 300 parts by weight of cracked yellow corn, 200 of oats, 100 of wheat bran, 300 of soybean oil meal, 70 of dehydrated alfalfa chops, 5 of limestone, 5 of steamed bonemeal, 5 of salt, and 0.25 of irradiated yeast (4,000,000 U.S.P. units of vitamin D per pound). The daily intake of starter was limited to 5 lb. for Holsteins, 4½ lb. for Ayrshires and Guernseys, and 4 lb. for Jerseys.

The calves were weighed at weekly intervals. Records were kept of all feed consumed. Daily health records were kept. Scours, colds, or other infections, when accompanied by a fever and requiring medication, were classified as severe. Infections not accompanied by fever were classified as slight. The designation of medium was given to infections that could not readily be classified as slight or severe.

If a calf had a severe infection, it was treated by a member of the College veterinary staff. Treatment usually consisted of the administration of penicillin (intra-muscularly) or sulfa drugs (per os). When calves had scours but no rise in body temperature, a tablespoonful of a mixture of 10 parts of kaolin and 1 part of pectin was given in the milk at each feeding until scouring ceased.

RESULTS AND DISCUSSION

The effects of streptomycin and of aureomycin on growth are shown in Figure 1 and Table 1. The first week's weight was used as the initial weight instead of the birth weight, since the latter weights were not available. Because of the difference in the average initial or first week's weight among the four treatment groups (Table 1), the use of a covariance analysis seemed indicated. However, from graphical analysis of the data (not presented), there appeared to be neither an important nor consistent within-treatment relationship between the first week's weight and the average daily gain during the next 15 weeks. Hence, a covariance analysis was not employed, but an analysis of variance was made of the average daily gains. Since the variability within blocks was at least as great as that among blocks, the incomplete block design employed in this experiment was not needed and the data were analyzed as a randomized complete block design.

The average daily gain of the calves receiving aureomycin was significantly greater than the average daily gain of the control calves and of those receiving either of the two levels of streptomycin. There was no significant difference

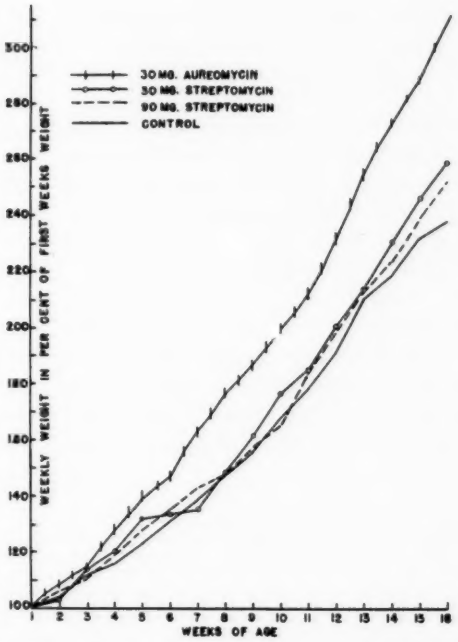

FIG. 1. Comparative growth response of two groups of calves receiving either 30 or 90 mg. of streptomycin daily per 100 lb. body weight, of one group receiving 30 mg. of aureomycin daily per 100 lb. weight, and of control calves.

between the average daily gains of the calves receiving the two levels of streptomycin, nor was the difference between the average daily gains of the calves receiving either level of streptomycin and the control calves significant.

The growth data from 1 to 16 weeks of age were further analyzed by employing the regression of weekly weight per pound of first week's weight on age. The slope of the aureomycin line (Figure 1) is significantly greater (Table 1)

TABLE 1

Effect of aureomycin and streptomycin on the growth of calves as measured by average daily gain and the linear regression of weight per pound of birth weight on age

Amt. antibiotic fed /100 lb. wt. daily	No. of calves	Av. 1st wk. wt.	Av. 16th wk. wt.	Av. daily gain		Regression coefficient *b*	
		(lb.)	*(lb.)*	*(lb.)*			
30 mg. aureomycin	9	82	242	1.52	*	14.33	*
90 mg. streptomycin	9	86	215	1.23	ns	10.54	ns
30 mg. streptomycin	9	85	211	1.20		10.95	
None (control)	9	78	178	0.95		9.96	

* = difference significant at the 0.05 level.
ns = difference not significant.

than the slope of the lines produced by any of the three other treatments. The slopes of the lines representing each of the other groups were similar. In general, these results of the regression analysis agree closely with those from the analysis of variance.

Although no growth response favorable to streptomycin feeding was found during the total 16-week period, nevertheless, study of the growth curves (Figure 1) indicates that there might have been some additional response from streptomycin during the first few weeks. Consequently an analysis of variance was made of the average weights of the calves at 5, 10, and 16 weeks of age expressed as a percentage of their first week's weight. Again the data were analyzed as a randomized complete block design.

At 5, 10, and 16 weeks of age, the calves receiving 30 mg. of aureomycin were significantly larger than the control calves (Table 2). At these three ages there were no significant differences between the sizes of the calves receiving either of the two levels of streptomycin, and neither level of streptomycin produced calves that were enough larger than the control calves to produce a significant differ-

TABLE 2

Effect of aureomycin and streptomycin on growth as measured by the average weights of the calves expressed as a percentage of their first week's weight

Amt. antibiotic fed /100 lb. wt. daily	No. of calves	5th wk. wt. in % of 1st wk. wt.	10th wk. wt. in % of 1st wk. wt.	16th wk. wt. in % of 1st wk. wt.
30 mg. aureomycin	9	138.6	199.2	309.6
		< ns	< ns	< *
30 mg. streptomycin	9	132.4	175.5	258.2
		*	*	
90 mg. streptomycin	9	127.7 — ns	168.3 — ns	252.1 — ns
None (control)	9	123.3	164.3	237.4

ns = difference not significant.
* = difference significant at the 0.05 level.

ence. At 5 and 10 weeks of age the average size of the calves receiving aureomycin was not significantly greater than that of the calves receiving either level of streptomycin. At 16 weeks the calves receiving aureomycin were significantly larger than the calves receiving either of the two levels of streptomycin. Therefore, it may be concluded that, under the conditions of this experiment, streptomycin appeared to produce a slight growth response, especially during the first few weeks of life. However, this response was not statistically significant nor as great as the response obtained with aureomycin.

Comparison of the effects of the two antibiotics on efficiency of gain showed that the aureomycin-fed calves required significantly less TDN and digestible protein per pound of gain during the period 1 to 16 weeks of age than did the control calves (Table 3). The aureomycin-fed calves also required less, though not significantly less, TDN and digestible protein per pound of gain than did the calves fed 30 mg. of streptomycin. The calves receiving 30 mg. of streptomycin required significantly less TDN and digestible protein per pound of gain than did the control calves. The calves receiving 90 mg. of streptomycin required less,

TABLE 3

Effect of aureomycin and streptomycin on efficiency gain of calves from 1 to 16 weeks of age

Amt. antibiotic fed /100 lb. wt. daily	No. of calves	TDN[a]/lb gain	Digestible protein[a]/lb gain
		(lb.)	*(lb.)*
30 mg. aureomycin	9	2.25	0.51
30 mg. streptomycin	9	2.45 *	0.58
90 mg. streptomycin	9	2.61 *	0.59 *
None (control)	9	2.94 *	0.67 *

[a] Calculated from Morrison's *(10)* tables.
* = difference significant at the 0.05 level.

though not significantly less, TDN and digestible protein per pound of gain than did the controls. Therefore, it appears that both aureomycin and streptomycin increased feed efficiency, with 30 mg. of aureomycin possibly being more effective than either 30 or 90 mg. of streptomycin. In three previous experiments *(1, 2, 3)* conducted at this station aureomycin-fed calves made more efficient gains than did control calves.

Study of the experimental treatments on calf health showed that the control calves had five slight, three medium, and seven severe infections. The calves receiving 30 mg. of aureomycin had no slight or medium infections and four severe. Those receiving 30 mg. of streptomycin had no slight infections, two medium, and five severe. Those receiving 90 mg. of streptomycin had two slight, three medium, and five severe infections. The limited data indicate that the two antibiotics had some influence in controlling the types of infections occurring in the environment of this experiment. Aureomycin appeared to be more effective than streptomycin in controlling these infections.

There was one outbreak of disease characterized by a high fever, coughing, and labored breathing, which resulted in the majority of severe infections encountered in this study. This outbreak occurred after several of the calves had completed the experiment but were still in the barn. Two control calves that had completed the experiment succumbed to the infection. All the antibiotic-fed calves responded to treatment, and none was lost.

Since initiation of this experiment, Hogue *et al. (8)* have published a preliminary report on the feeding of streptomycin to dairy calves. They fed young calves aureomycin, streptomycin, and a mixture of two other antibiotics. Three antibiotic levels (10, 20, or 40 mg. per 100 lb. body weight per day) and two durations of antibiotic feeding (7 or 16 weeks) were tested. Both aureomycin and streptomycin significantly ($P < 0.05$) increased the daily gain for the first 7 weeks. The gain of the calves receiving aureomycin averaged 1.00 lb. per day and was superior to the gain of the calves receiving streptomycin, which was 0.92 lb. per day. The control calves gained 0.78 lb. per day. No significant differences among treatments were observed at 16 weeks and no advantage was shown for any particular level of antibiotic. However, results reported herein

differ from the findings of Hogue *et al.* in that streptomycin did not produce so great a growth response but support their results in that aureomycin stimulated growth to a greater extent than did streptomycin.

Hogue *et al.* also reported that aureomycin and streptomycin each significantly ($P < 0.05$) increased feed efficiency during the first 7 weeks. The calves receiving aureomycin required 1.91 lb. of TDN per pound of gain, those receiving streptomycin required 2.06 lb., and the control calves required 2.34 lb. These results are in harmony with the results of the experiment herein reported.

Hogue *et al.* similarly reported that aureomycin and streptomycin decreased the incidence of scours during the first 7 weeks. However, in their work aureomycin and streptomycin were about equally effective in controlling scours, whereas in the experiment reported here aureomycin was more effective than streptomycin. Therefore, the poorer growth response obtained from streptomycin in the present study may have been due to a relative ineffectiveness of streptomycin to control some of the types of infections encountered.

SUMMARY

This experiment was initiated to compare the effects of streptomycin with aureomycin on the growth and well-being of young dairy calves. Thirty-six calves were divided into four groups with nine calves each. Calves in one group received 30 mg. aureomycin daily for each 100 lb. of calf weight, a second group received 30 mg. of streptomycin, a third group received 90 mg. of streptomycin, and a fourth received no antibiotic and served as a control. All calves were started on the experiment at birth and continued until 16 weeks of age.

Both levels of streptomycin appeared to produce a slight growth stimulation, especially during the first few weeks of life, but this stimulation was not statistically significant nor so great as the stimulation obtained with aureomycin. The calves receiving aureomycin grew at a significantly faster rate than the control calves. Both streptomycin and aureomycin appeared to reduce the incidence of calf infection; however, aureomycin appeared to be slightly the more effective of the two. Also, both streptomycin and aureomycin-fed calves required less TDN and digestible protein per pound of gain than the control calves. The aureomycin-fed calves made more efficient gains than those fed streptomycin.

In general, there was no difference between the two levels of streptomycin in regard to rate of weight gain, incidence of disease, or feed efficiency.

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RELATIONS BETWEEN PARTS OF LACTATIONS AND PRODUCING ABILITY OF HOLSTEIN COWS[1]

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Partial records may be useful in improving annual milk and fat production. Frequently selection decisions must be made before a record is complete. Preliminary sire evaluation can be had earlier if partial records can be used in sire proofs. The present study was undertaken to ascertain the repeatability, heritability, and genetic correlations for various parts of the lactation. These statistics permit answers to such questions as *(a)* the relative accuracy of various parts of the lactation for predicting the entire lactation and *(b)* the extent to which the same genes operate during various parts of the lactation.

Several workers have considered correlations between various cumulative periods of production in consecutive and nonconsecutive lactations *(4, 5, 6, 15)*. Gifford *(5)* also studied correlations between production for the same single month period in consecutive lactations.

Estimates of heritability based on daughter-dam regressions and correlations or on paternal half-sib correlations have been reported for cumulative production periods of 180 up to 365 days *(9, 11, 15, 18)*.

The genetic correlation between a part and the entire lactation has been reported only once *(17)*. Essentially the same method was used earlier with egg production records *(12)*. The relative efficiency of using part records as the basis of selection for the whole record has not been reported previously for milk and butterfat production but has been utilized by Lerner and Cruden *(12)* to improve selection for annual egg production in poultry.

Extrapolation factors for predicting 305- or 365-day production from a single test, from the average of several monthly tests, or from cumulative production have been reported *(1, 3, 6, 19)*. Several workers *(3, 7, 16)* have reported prediction equations suitable for various ages.

PROCEDURE

All production records, at least 243 days in length, completed in the Iowa State College Holstein herd from 1940 to 1952, inclusive, were studied. Every milking was weighed and the fat was tested one day each month. From these data the milk and butterfat productions for 30-day monthly and cumulative intervals were calculated. Records were corrected to a 2 × M.E. basis, using the

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[2] These studies were conducted by the senior author while a research assistant at the Iowa Agricultural Experiment Station.

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TABLE 1

Means and coefficients of variation for monthly and cumulative periods (599 records—2 × M.E.)

Days	Milk		Fat	
	Mean	Coefficient of variation	Mean	Coefficient of variation
1-30	1,537	20.4	55.2	23.9
31-60	1,701	19.3	56.7	21.0
61-90	1,633	19.0	53.3	20.3
91-120	1,514	19.6	49.6	20.6
121-150	1,403	19.9	46.8	20.7
151-181	1,330	20.6	44.9	21.4
182-212	1,205	22.5	41.5	22.4
213-243	1,075	26.0	38.1	26.2
244-274	907	35.4	33.5	34.6
275-305	658	56.9	24.8	54.4
1-60	3,238	19.2	111.9	21.2
1-90	4,871	18.5	165.2	19.9
1-120	6,385	18.2	214.8	19.1
1-150	7,788	17.9	261.7	18.6
1-181	9,118	17.7	306.5	18.3
1-212	10,323	17.5	348.0	17.9
1-243	11,392	17.4	385.8	17.7
1-274	12,293	17.7	418.9	17.7
1-305	12,947	18.3	443.6	18.3

D.H.I.A. factors *(10)*. Five hundred ninety-nine records by 253 cows were studied. Table 1 shows the means and coefficients of variation for monthly and cumulative periods.

The difference between actual and age-corrected monthly means showed that the age correction factors *(10)*, which had been derived from 305-day lactation totals, were fairly suitable for correcting the center months but were in error for the extreme months. These errors were largest for records begun at ages less than 3 years, which means first records almost entirely. This merely reemphasizes the well-known fact that cows are more persistent in their first lactation than in later lactations. When the age correction factors were applied to progressively longer cumulative periods, they were more adequate. Little difference was noted between levels of age-corrected 305-day production of first and later lactations.

Repeatabilities were computed as intraclass correlations by using variance components obtained by the analysis of variance. Heritabilities and genetic correlations were computed from intrasire regressions of daughter production on dam production *(8, 13)*.

RESULTS AND DISCUSSION

Extrapolation factors. When average monthly production was plotted separately for the various age groups, the lactation curves were distinctly different for records begun before 3 years and for later lactations. The greater persistency in records made at the younger ages requires different factors for various ages to extrapolate short-time records to a 305-day basis in an unbiased way. Such factors were computed from the actual cumulative production averages for the

TABLE 2
Factors for multiplying the actual cumulative part records to estimate the 305-day production

Days	Lactations begun at ages: Less than 3 yr. (257 records) Milk	Less than 3 yr. (257 records) Fat	3 yr. or older (342 records) Milk	3 yr. or older (342 records) Fat	D.H.I.A. factors *(2)*
30	9.36	9.00	7.81	7.40	7.692
60	4.38	4.36	3.74	3.70	3.846
90	2.87	2.91	2.52	2.53	2.614
120	2.17	2.21	1.93	1.97	2.010
150	1.76	1.80	1.60	1.63	1.660
181	1.49	1.52	1.37	1.40	1.430
212	1.30	1.32	1.22	1.24	1.270
243	1.16	1.18	1.12	1.13	1.153
274	1.06	1.07	1.04	1.05	1.067
305	1.00	1.00	1.00	1.00	1.000

two age groupings and are shown in Table 2. Obviously, separate factors are indicated for first records compared with later records for at least the first 150 days. Otherwise, first records extrapolated from the early part of the lactation will, on the average, be seriously underestimated. Factors for the various later ages did not differ enough from each other to warrant separate factors. Because of the small volume of the present data, some further study on this question seems warranted.

Repeatabilities. Correction of partial records for age failed to remove age effects wholly, especially when applied to records begun before 3 years of age. An attempt was made to remove the rest of the age effects by considering as separate ages the records begun before and after 3 years of age in all the analyses of variance of the pattern shown in Table 3. Simultaneous solution of three of the expected mean squares equations, when equated to the computed mean squares, gave values for the components σ^2_e, σ^2_c, and σ^2_a. The variance represented by σ^2_e consists of temporary environmental effects assumed to be random from one lactation to another. Permanent differences between cows caused the variance represented by σ^2_c. Variation represented by σ^2_a results from those influences which cause average production in one age group (less than 3 years) to differ from average production in the other age group (3 years or older). The σ^2_a component was a way of removing statistically most of the age effects which had not been removed wholly by the age correction factors.

TABLE 3
Structure of the analysis of variance between ages and between cows

Source of variance	d.f.	Expected mean squares
Total	598	$\sigma^2_e + 0.491\,\sigma^2_a + 0.996\,\sigma^2_c$
Between ages	1	$\sigma^2_e + 293.469\,\sigma^2_a + 0.820\,\sigma^2_c$
Between cows	252	$\sigma^2_e + 0.399\,\sigma^2_a + 2.363\,\sigma^2_c$
Remainder	345	$\sigma^2_e - 0.291\,\sigma^2_a - 0.002\,\sigma^2_c$

Considering 10 months singly and cumulatively for milk and fat required 40 tables such as Table 3. In the total of the age, cow, and error components for these various tables, the age component runs from as low as 0% to as high as 36% of the total. The age component was much higher for the first few months and last months when considered singly and for the first five cumulative months than for the middle single months or the long-time cumulative totals.

Repeatability was computed as an intraclass correlation expressed as $\frac{\sigma^2_c}{\sigma^2_c + \sigma^2_e}$. This is the correlation between records by the same cow. Repeatability values *(r)* for monthly and cumulative periods of milk and butterfat production are listed in Table 4.

TABLE 4

Repeatability (r) and intra-sire regression (b) of daughter on dam for monthly and cumulative periods

	Milk		Fat	
Days	r	b	r	b
1-30	0.547	0.195	0.515	0.142
31-60	0.590	0.180	0.501	0.158
61-90	0.528	0.164	0.417	0.126
91-120	0.430	0.155	0.322	0.137
121-150	0.419	0.183	0.311	0.129
151-181	0.417	0.204	0.324	0.088
182-212	0.354	0.193	0.260	0.101
213-243	0.299	0.188	0.199	0.070
244-274	0.258	0.084	0.151	0.011
275-305	0.280	–0.038	0.216	–0.073
1-30	0.547	0.249	0.515	0.198
1-60	0.599	0.226	0.569	0.213
1-90	0.609	0.197	0.572	0.176
1-120	0.600	0.172	0.548	0.150
1-150	0.589	0.195	0.532	0.154
1-181	0.581	0.236	0.521	0.180
1-212	0.567	0.274	0.509	0.221
1-243	0.545	0.304	0.481	0.236
1-274	0.521	0.316	0.453	0.223
1-305	0.510	0.291	0.434	0.187

Gifford *(5)* reported in an unpublished investigation that correlations between production records for corresponding single months in consecutive lactations by the same cow actually increased up to the ninth and tenth months.

Repeatability of milk and fat production for 243 days up to 305 days has generally been reported to be of the order of 0.3 to 0.5. Correlations between cumulative parts for shorter periods have been reported *(4, 5, 15)* to be as high as 0.5 to 0.6 on an intraherd basis.

The decreased repeatabilities and heritabilities for the later single months in Table 4, as well as the increased coefficients of variation for these months in Table 1, indicate that production during the later months of the lactation is determined more by temporary environmental influences and less by permanent differences between cows than is production during the early months. This seems to indicate that persistency of production is determined primarily by extraneous

environmental sources and is not affected much by the inherent qualities of the cow herself.

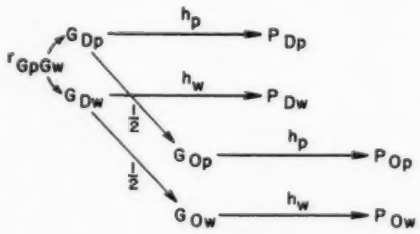
Heritability. Heritability, when obtained by doubling the intrasire regression of daughter's production on dam's production, is a measure of that portion of the total variation which is due to additively genetic variation *(13)*. Twenty different sires had 157 daughters in this study and 67% of the dams had a single daughter. When a dam had more than one daughter, the dam's record was repeated with the record of each daughter. The intrasire regressions *(b)* for monthly and cumulative milk and butterfat production are listed in Table 4. The regressions for monthly periods were computed by using averages of all records of the cow and were then corrected to a single record basis by the formula presented by Lush and Straus *(14)*. The regressions for cumulative periods were computed by using first records of the 154 daughter-dam pairs where this record began at ages under 3 years.

Shrode and Lush *(18)* indicate that estimates of heritability of intraherd differences in milk and butterfat production have been of the order of 0.2 to 0.3 from most studies where lactation length ranged from 243 to 365 days.

Mahadevan *(15)* obtained a heritability estimate of 0.31 for first 180-day production for 903 daughter-dam pairs of Ayrshire cows. Using the average of all 180-day yields made by 732 Ayrshire daughter-dam pairs and calculated on a single record basis, he obtained a heritability value of 0.27, indicating a slightly higher value for first record.

Reasonably rapid progress would be expected from mass selection on the basis of part records, especially when heritability values are of the order of 0.5 to 0.6. The rate of progress would naturally depend upon the intensity of selection possible in the dairy herd.

Genetic correlations. Genetic correlations were computed between various



$$r_{GpGw} = \sqrt{\frac{(\text{Cov } P_{Dp}\ P_{Ow})(\text{Cov } P_{Dw}\ P_{Op})}{(\text{Cov } P_{Dp}\ P_{Op})(\text{Cov } P_{Dw}\ P_{Ow})}}$$

$$h_i = \frac{\sigma_{Gi}}{\sigma_{Pi}} \quad \text{and} \quad r_{G_D\,G_O} = \frac{1}{2}$$

FIG. 1. Genetic relations between dam and daughter for part and whole production.

cumulative parts and the cumulative 8-, 9-, and 10-month production by the method of Hazel *(8)*. First lactations initiated at less than 3 years of age for 154 daughter-dam pairs were used. The genetic relations between part and whole record for both dam and daughter are indicated in Figure 1, where G and P represent genic and phenotypic values, respectively; D and O refer to dam and daughter, respectively; and p and w refer to part and whole record, respectively. Four correlations are possible between the phenotype of dam and daughter. These correlations, or the corresponding covariances, are substituted in the equation shown in Figure 1. This provides an estimate of the genetic correlation between part and whole record. The estimates are listed in Table 5.

TABLE 5

Genetic correlations between cumulative part records and whole records

Length of cumulative record	Length of whole record (days)					
	Milk			Fat		
	243	274	305	243	274	305
(days)						
30	0.91	0.92	0.96	0.96	1.02	1.17
60	1.01	1.01	1.05	0.99	1.02	1.13
90	1.05	1.06	1.12	1.02	1.06	1.20
120	1.02	1.04	1.12	1.01	1.04	1.20
150	1.02	1.05	1.12	1.03	1.06	1.20
181	1.01	1.03	1.08	1.02	1.04	1.13
212	1.00	1.01	1.05	1.00	1.02	1.08
243		1.00	1.02		1.01	1.05
274			1.01			1.01

The familiar automaticity in part-whole correlations does not influence the magnitude of these genetic correlations since the phenotypic correlations used are all between one trait in the dam and the same or another trait in the daughter.

While sampling errors may cause correlations to exceed unity where they are thus computed from ratios between correlations, it is difficult to explain the trends in these correlations as the cumulative part approaches the whole record in length. These correlations would be expected to be high because it seems probable that genes which affect one part of the lactation would somewhat affect other stages of the lactation. However, it also seems probable that some genes would somewhat alter the shape of the lactation curve. The figures obtained seem even higher than expected, but no explanation for that, except the possibility of sampling errors, was found.

Robertson *(17)*, using intrasire daughter-dam covariances based on about 1,300 degrees of freedom, obtained a genetic correlation of 0.76 $\pm$ 0.14 between 70-day yield and 305-day yield. Robertson states that this is not significantly different from unity.

High genetic correlations between part and whole lactations imply that the genes which affect production in the early parts of the lactation affect other parts of the lactation similarly. Genetic correlations near unity indicate that selection on the basis of part records may be accurate enough actually to increase genetic progress by permitting earlier evaluation, even though part records

may be somewhat less accurate than the whole record would be if one could wait for that.

Relative efficiency of selection. According to the method reported by Lerner and Cruden *(12)*, the relative efficiency of selection for whole record by using part records as the selection criterion is indicated by the ratio $\frac{\Delta\, Gwp}{\Delta\, Gw}$ where the numerator represents genetic progress in whole record when selection is on the basis of part record and the denominator represents genetic progress when selection is based on whole record. $\Delta\, Gwp = r_{GwPp}\, h_w\, \sigma_{Pw}\, z/v$ while $\Delta\, Gw = h^2_w\, \sigma_{Pw}\, z/v$. The ratio then becomes $\frac{r_{GwPp}}{h_w} = \frac{r_{GwGp}\, h_p}{h_w}$. In cases where the computed genetic correlation (r_{GpGw}) exceeded unity, unity was used to obtain $\Delta\, Gwp$.

TABLE 6

Relative efficiency of selection for whole record by using cumulative part record as the selection criterion

Cumulative part record	Length of whole record *(days)*					
	Milk			Fat		
	243	274	305	243	274	305
(days)						
30	0.82	0.82	0.89	0.88	0.94	1.03
60	0.86	0.84	0.88	0.94	0.98	1.07
90	0.80	0.79	0.82	0.86	0.89	0.97
120	0.75	0.74	0.77	0.80	0.82	0.90
150	0.80	0.78	0.82	0.81	0.83	0.91
181	0.88	0.86	0.90	0.87	0.90	0.98
212	0.95	0.93	0.97	0.97	1.00	1.09
243	1.00	0.98	1.02	1.00	1.03	1.12
274		1.00	1.04		1.00	1.09
305			1.00			1.00

Table 6 contains the values found for the relative efficiency of selection for whole record by using the part record as the selection criterion. Part records are cumulative milk and butterfat production and whole records are 243-, 274-, and 305-day production for the same characters. Selection on the basis of first 60-day production best approaches the gain expected in the whole record until the part record is 6 months or more in length. This seems to indicate that first 60- to 90-day production should be considered in preference to selection on a longer record, until the longer record is 6 months or more in length.

SUMMARY

The relations between various parts of completed lactations of at least 243 days duration were considered in 599 lactations of 253 Holstein cows in the Iowa State College herd.

Factors for estimating 305-day production from cumulative part records need to be different in first lactations and in later lactations.

Average repeatabilities for single month milk and fat production and for cumulative month milk and fat production were 0.41, 0.32, 0.57, and 0.51, respectively. Average intrasire daughter-dam regressions for single month milk and fat production and for cumulative month milk and fat production were 0.15, 0.09, 0.25, and 0.19, respectively. Genetic correlations between cumulative part and whole milk and fat production were over 0.9. Selecting on the cumulative part record would improve production nearly as much as selecting on the complete record itself, the efficiency values ranging from 0.74 to above unity.

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EFFECTS OF VACUUM LEVEL AND MILKING DURATION ON GUERNSEYS AND HOLSTEINS DIFFERING WITH RESPECT TO LACTATION NUMBER AND STATUS OF UDDER HEALTH.

I. UDDER HEALTH[1]

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The effects of vacuum level and machine milking duration on udder health are controversial *(2, 8, 11)*. Although observations from field studies suggest that both of these factors might be detrimental to udder health, data from controlled experimentation have failed to relate vacuum level and udder health *(6, 7, 9, 10, 13)*. With regard to machine milking duration, Dodd *et al. (4)* reported a greater incidence of clinical and subclinical mastitis in first-calf heifers subjected for their entire lactation to an 8-minute duration than in heifers subjected to a 4-minute duration. In possible contrast, half-udders of first-calf mastitis-free heifers subjected for a 40-week experimental period to either a "normal" or "twice normal" milking duration did not have significantly different incidences of clinical mastitis, occurrences of mastitis organisms, or histological changes *(6, 9)*. Similar findings were reported *(10)* for cows more advanced in the number of lactations and whose whole udders were milked for "normal," "twice normal," or "four normal" durations for 6 weeks. Log of leucocyte count and chloride content, however, were affected by milking duration in the latter two studies *(9, 10)*. In the first-calf mastitis-free heifers, normal duration halves of udders had a greater log leucocyte number and chloride concentration than twice normal halves, whereas in the second study a direct relationship of log leucocyte count and chloride content with the log of milking duration was observed. The results from halves of udders were unexpected and difficult to evaluate; however, those from whole udders were interpreted as irritation directly attributable to increased milking duration.

In light of these rather contradictory results, the present project was undertaken to determine the effects on the udder health of Guernseys and Holsteins, differing in number of lactations and status of udder health at the beginning of the experiment, when whole udders were milked at one of three vacuum levels and for a normal or an excessive milking duration.

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EXPERIMENTAL PROCEDURE

Animals. Forty-eight Guernsey and Holstein first-calf heifers and cows from the University of Connecticut herd (*Streptococcus agalactiae*–free) were on experiment from August, 1952, through July, 1953. These were selected from animals which were due to calve during this period. They were subjected during the first 4 weeks of lactation, the standardizing period, to uniform conditions of feeding and management and were milked at 13.5 in. of vacuum for a minimum duration as determined by the milking machine operator.

Of these animals, 24 were Guernseys and 24 were Holsteins. Within each breed group, 12 were first-calf heifers and 12 were in their second or subsequent lactation. Within each breed-lactation subgroup of 12, six were selected for being "infected" and six for being "clean." Infected animals were those *(a)* which had an attack of clinical mastitis during the standardizing period and/or *(b)* which had leucocyte counts greater than 500,000 per milliliter in two or more of the four samples drawn during the third and fourth week postpartum and/or *(c)* which had mastitis organisms present in two or more of these samples. All other animals were considered clean. Average age, previous lactations, length of lactation, gestation time, and live weights of these animals are included in Table 1.

At the beginning of the fifth week postpartum, the six animals within each breed, lactation, and infection grouping were randomly assigned to be milked

TABLE 1

Average age, previous lactations, length of lactation, gestation time, and live weight by experimental groupings

Expt. classification	Age at calving	Previous lactations	Length of expt. lactation	Duration of gestation at completion of experiment	Live weight	
					Standardizing period	End of comparison period
	(years)	*(No.)*	*(weeks)*	*(days)*	*(lb.)*	
Vacuum level						
10 in.	4.0	1.6	43.9	179	1,081	1,115
13.5 in.	4.2	1.6	43.6	196	1,179	1,190
17 in.	3.4	0.9	43.9	174	1,073	1,113
Milking duration						
Normal	3.9	1.5	43.8	185	1,116	1,133
Twice normal	3.8	1.2	43.8	180	1,106	1,149
Infection						
Clean	3.5	1.2	43.6	183	1,058	1,115
Infected	4.2	1.5	44.0	182	1,164	1,166
Lactation						
Heifer	2.4	0.0	44.0	185	990	1,052
Cow	5.2	2.8	43.6	181	1,232	1,226
Breed						
Guernsey	4.0	1.7	43.6	200	976	997
Holstein	3.7	1.1	44.0	166	1,246	1,267
Standard deviation of an animal	0.8	1.0	0.6	70	115	131

at one of three vacuum levels and for one of two milking durations. The vacuum levels used were 10.0, 13.5, and 17.0 in. of mercury. The milking durations used were normal and twice normal. Normal duration was defined as the length of time from attaching the machine to the udder until the rate of flow, as determined by suspending the milker unit from a hanging scale, dropped to 0.2 lb. or less for a 15-second interval *(1)*. Twice normal was twice the normal duration for the particular cow concerned. The animals were milked at their assigned treatments from the fifth through the 44th week postpartum (or until dry), the comparison period.

In the comparison period normal milking time was determined for both milkings on the first day of each 28-day period. The cows were machine stripped immediately after the normal or twice normal duration. The average of the morning and evening durations was used for the 27 days following each determination. Milking was carried out with upright claw-type milkers operating at 48 to 50 pulsations per minute. The method of preparing the animals for milking and the handling of the milking machines were identical to methods previously described *(9, 10)*.

The only animals treated for mastitis were those with abnormal appearing milk accompanied by a body temperature of 104° F. or more and those with an inflamed swollen udder and a temperature of 103° F. or more. Treatment consisted of sodium sulfamethazine administration, first intravenously, followed by capsules orally for 3 days; quarters which were bacteriologically positive for mastitis organisms were infused twice with one tube of aureomycin[4] at a 48-hour interval. Chronic mastitis cases, in evidence only from strip cup examination, were not treated.

All cows not shedding mastitis organisms were milked first. Those shedding hemolytic staphylococci in two consecutive weekly samples were milked second as a group, and those shedding mastitis streptococci or coliform organisms in two consecutive samples were milked last. Cows that had been milked second or last were again milked with the first group if no mastitis organisms were isolated from three consecutive weekly samples.

Feeding. For 30 days prior to the calculated calving date all animals were fed a standard grain ration[5] at 0.5 lb. per 100 lb. live weight daily. For the first two 28-day periods postpartum the cows received 1.0 lb. of the same grain ration per 100 lb. live weight. For the third and remaining 28-day periods they were fed grain at 1.0 lb. for each 4.0 lb. of fat-corrected milk (FCM) produced *(5)* in the middle of the preceding period. The amount of grain fed on an FCM basis was not allowed to fall below an amount equal to 0.5 lb. per 100 lb. live weight.

[4] Lederle aureomycin hydrochloride for udder infusion containing 426 mg. aureomycin per tube.

[5] This grain mixture contained the following ingredients in pounds per ton: 660, crimped oats; 400, hominy feed; 320, wheat bran; 340, linseed oil meal o.p.; 200, molasses; 40, salt, and 40, steamed bone meal, and averaged 15.5% crude protein content.

Throughout the trial all animals were fed a grass mixed hay[6] ad libitum and approximately 20, 30, and 45 lb. daily of grass or corn silage for the Guernsey heifers, Holstein heifers and Guernsey cows, and Holstein cows, respectively. In season, pasture replaced the silage in the ration.

Criteria and analyses. Twice weekly during the standardizing period and once weekly during the comparison period, approximately 10 ml. of milk was drawn aseptically from each quarter 2 to 4 hours after the morning milking. The four quarter samples from each cow were pooled for the determination of leucocyte count (to the nearest 10,000 per milliliter up to one million and to the nearest 100,000 over one million) and chloride content as previously described *(9)* and for the presence or absence of mastitis organisms in the fresh milk by routine procedures *(12)*. A complete history of clinical mastitis cases was recorded.

Milk weights were recorded at each milking to the nearest 0.1 lb., and a 2-day aliquot milk sample from each cow was taken in the middle of each 4-week period for fat determination by a modified Babcock method *(16)*.

During the standardizing period and again during the last 4 weeks of the comparison period physical examinations of each cow's teats and udder were made by three veterinarians. Their scores for redness, openness, vegetation, proliferation, and congestion of the teats and for fibrosis of the udders according to Udall *(15)* were averaged.

An analysis of variance was made to determine the effect of breed, age, infection, vacuum level, milking duration, and the first and second order interactions of the named main effects. Higher order interactions were regarded as negligible and therefore were used as an estimate of error variance *(3)*. In addition to the average response for the entire comparison period, time trends were explored by separate analyses of first and second order orthogonal polynomial coefficients *(17)*. Adjustment of the data obtained during the comparison period to those of the standardizing period by the method of covariance *(3)* produced no significant reduction ($P > 0.05$) in the error mean squares.

RESULTS

Leucocyte count and chloride content. Averages of the logarithm of the leucocyte count per milliliter times 10^{-4} and chloride content in milligram per cent for both the standardizing and the comparison period, as well as weekly rates of change during the comparison period, expressed as linear and quadratic functions of orthogonal polynomial coefficients, are contained in Table 2. Vacuum level and milking duration were without statistically significant effect on the averages of these criteria. A greater weekly increase in chloride content was observed for animals milked at the 13.5 in. vacuum level than for those at the 10 and 17 in. levels ($P < 0.05$). The animals subjected to the twice normal dura-

[6] The hay graded on the average U. S. No. 1.6 timothy mixed, contained 7.0% foreign material, consisted of 44.4% timothy, 18.1% legumes, and 37.5% other grasses, and had 48.3% green color.

TABLE 2

The effect of vacuum level, milking duration, degree of infection, lactation, and breed on chloride content and leucocyte counts of milk

Expt. classification	Leucocytes				Chlorides			
	Standardizing period	Comparison period			Standardizing period	Comparison period		
			Weekly rate of change[a]				Weekly rate of change[a]	
	Av.	Av.	Linear	Quadratic	Av.	Av.	Linear	Quadratic
	[*log (count/ml)* × 10^{-4}]				(*mg. %*)			
Vacuum level								
10 in.	1.870	1.755	0.006	0.191	106	129	1.78	0.04
13.5 in.	1.644	1.721	0.011	0.184	102	140	2.48	0.01
17 in.	1.749	1.701	0.005	0.610	95	131	1.82	0.13
Milking duration								
Normal	1.761	1.774	0.002	0.265	96	134	1.84	0.00
Twice normal	1.748	1.678	0.012	0.392	105	133	2.21	0.12
Infection								
Clean	1.374	1.483	0.014	0.206	97	131	2.16	0.09
Infected	2.134	1.969	0.000	0.451	104	136	1.89	0.03
Lactation								
Heifer	1.670	1.463	0.001	0.437	94	115	1.46	0.00
Cow	1.839	1.989	0.014	0.220	107	151	2.59	0.12
Breed								
Guernsey	1.834	1.689	0.005	0.489	96	124	2.13	0.03
Holstein	1.675	1.763	0.009	0.168	106	143	1.92	0.09
Standard deviation of an animal	0.167	0.356	0.011	0.869	19	20	0.70	0.28

[a] Expressed as orthogonal polynomial coefficients *(16)*.

tion had more rapid linear weekly increases in leucocyte number ($P < 0.05$) and in chloride content ($P < 0.10$) than those milked at the normal duration.

To explore possible initial effects of changing vacuum level and milking duration, calculations of the responses for the first 6 weeks of the comparison period were made. Average leucocyte counts for the 6 weeks, expressed as logarithms of the count times 10^{-4}, were 1.71, 1.55, and 1.65 for the 10, 13.5, and 17 in. vacuum levels, respectively, and 1.76 and 1.51 for the normal and twice normal durations with a standard deviation per animal of 0.42. Similarly values for the chloride content in milligrams per cent were 105, 99, 104, and 103 and 103 for the vacuum level and duration treatments with a standard deviation per animal of 18. With the exception of slightly higher leucocyte numbers in the normal duration group than in the twice normal ($P < 0.10$), no other effects of vacuum level or milking duration were observed for the first 6 weeks of the comparison period.

The milk from animals classified clean with respect to mastitis during the standardizing period had fewer leucocytes on the average and lower weekly rates of increase of leucocytes during the comparison period than did the milk from animals classified as infected ($P < 0.01$). The milk from first-calf heifers had fewer leucocytes and a less pronounced weekly rate of increase of leucocytes than did the milk from those animals with one or more previous lactations

TABLE 3

The effect of vacuum level, milking duration, degree of infection, lactation, and breed on the absence of mastitis organisms and the clinical cases of mastitis

Expt. classification	Percentage of milk samples free of mastitis organisms				Clinical cases of mastitis							
					Standardizing period				Comparison period			
	Standardizing period		Comparison period									
	Angle[a]	Per cent[b]	Angle[a]	Per cent[b]	Total cases	No. of animals	$\sqrt{\text{Av. No. cases per animal} + \frac{1}{2}}$	Av. No.[c] cases per animal	Total cases	No. of animals	$\sqrt{\text{Av. No. cases per animal} + \frac{1}{2}}$	Av. No.[c] cases per animal
Vacuum level												
10 in.	65.62	83	59.53	74	0	0	0.71	0.00	0	0	0.71	0.00
13.5 in	68.44	86	66.01	83	0	0	0.71	0.00	9	3	0.92	0.35
17 in.	76.88	95	71.20	90	2	2	0.77	0.09	3	2	0.80	0.14
Milking duration												
Normal	71.25	90	65.00	82	1	1	0.73	0.03	11	4	0.88	0.27
Twice normal	69.38	88	66.16	84	1	1	0.73	0.03	1	1	0.73	0.03
Infection												
Clean	88.75	100	76.85	95	0	0	0.71	0.00	3	1	0.76	0.08
Infected	51.88	62	54.31	66	2	2	0.75	0.06	9	4	0.86	0.24
Lactation												
Heifer	80.00	97	72.01	90	0	0	0.71	0.00	7	3	0.82	0.17
Cow	60.62	76	59.15	74	2	2	0.75	0.06	5	2	0.79	0.62
Breed												
Guernsey	65.62	83	66.22	84	1	1	0.73	0.03	5	1	0.78	0.61
Holstein	75.00	93	64.94	82	1	1	0.73	0.03	7	4	0.84	0.21
Standard deviation of an animal	14.82	—	17.84	—	–	–	0.39	—	–	–	1.18	—

[a] Angle = arc sin $\sqrt{\text{percentage of samples free of mastitis organisms}}$ *(13)*.

[b] Angle transformed back to percentages.

[c] Av. of $[(\sqrt{\text{no. of cases per animal}} + \frac{1}{2})^2 - \frac{1}{2}]$ *(13)*.

($P < 0.01$). In this experiment, the milk from Holsteins had a greater number of leucocytes and a higher chloride content than did the milk from Guernseys; however, only the difference for chlorides was found to be statistically significant ($P < 0.01$).

Mastitis. The angles *(14)* of the percentage of the milk samples free from mastitis organisms during the last 2 weeks of the standardizing period and the entire comparison period and the square roots of the number of clinical cases of mastitis plus one-half *(14)* in both the standardizing and comparison periods are presented in Table 3. Neither vacuum levels nor milking duration had an appreciable effect on the per cent of observations free from mastitis organisms. As might be expected, clean animals and first-calf heifers had greater percentages of samples free of mastitis organisms than did infected animals ($P < 0.01$) and those with one or more previous lactations ($P < 0.05$).

Twelve cases of clinical mastitis[7] (animals exhibiting rectal temperatures of 103° F. or above and yielding an udder secretion that contained mastitis organisms and a leucocyte count greater than 500,000) were observed during the comparison period. Statistical analysis failed to demonstrate significant differences due to any of the experimental classifications.

Udder and teat-end scores. The square root of the udder fibrosis and teat-end scores plus one-half *(14)* are given in Table 4. Animals classified infected and those with one or more previous lactations had higher udder fibrosis scores than clean animals and first-calf heifers. Although in general teat-end scores tended to be higher with either an increase in vacuum level or an increase in milking duration, these differences were found not to be statistically significant. The high standard deviations per animal of the teat-end scores in relation to their respective means (i.e., the coefficient of variation) indicated that these scores were less precise than the leucocyte count, chloride content, and percentage of the milk samples free from mastitis organisms.

DISCUSSION

It seems reasonable to assume that vacuum per se has little or no direct effect on udder health over the levels studied in this experiment. The greater weekly increase in chloride concentration in milk from animals milked at 13.5 in. of vacuum can be discounted in view of the failure to demonstrate an effect of vacuum level on leucocyte count, percentage of samples free from mastitis organisms, clinical cases, and histopathological changes in udder tissue as reported in this paper and in other studies *(6, 7, 9, 10, 13)*.

Leaving the milker attached to the udder after milk flow has decreased to a very low rate (the twice normal duration) brought about more rapid weekly increases in leucocyte and chloride values of the milk, thereby confirming a previous study from this station *(10)*. However, no appreciable change was

[7] During the standardizing period, two clinical cases of hemolytic staphylococci were identified by standard laboratory procedures *(12)*. During the comparison period there were eight clinical cases of coliform, three of hemolytic staphylococci, and one of *Str. uberis*.

TABLE 4

The effect of vacuum level, milking duration, degree of infection, lactation, and breed on udder fibrosis and teat-end scores

Experimental classification	Udder fibrosis scores[a]		Teat-end scores[b]											
			Openness		Proliferation		Redness		Vegetation		Congestion		Total	
	Standardizing period	Comparison period	Standardizing period	Comparison period	Standardizing period	Comparison period	Standardizing period	Comparison period	Standardizing period	Comparison period	Standardizing period	Comparison period	Standardizing period	Comparison period
	($\sqrt{\text{Score}} + \frac{1}{2}$)													
Vacuum level														
10 in.	2.8	2.8	1.0	1.0	1.2	1.6	1.9	1.2	0.7	0.8	1.0	1.2	5.8	5.8
13.5 in	2.6	2.9	0.9	1.0	1.1	1.3	1.9	1.4	0.8	1.0	1.1	1.4	5.8	6.2
17 in.	2.3	2.7	1.1	1.2	1.5	1.6	2.0	1.3	1.0	1.0	1.2	1.5	6.8	6.6
Milking duration														
Normal	2.6	2.8	1.0	1.0	1.3	1.4	1.8	1.4	0.8	0.9	1.1	1.3	6.1	6.1
Twice normal	2.6	2.8	1.0	1.1	1.3	1.5	1.9	1.2	0.9	1.0	1.1	1.4	6.2	6.3
Infection														
Clean	2.4	2.7	0.8	1.1	1.2	1.3	1.9	1.3	0.7	1.0	1.1	1.4	5.7	6.1
Infected	2.7	2.9	1.2	1.1	1.4	1.6	1.9	1.3	1.0	1.0	1.2	1.3	6.6	6.3
Lactation														
Heifer	2.6	2.7	0.9	1.1	1.3	1.4	2.1	1.3	0.8	1.0	1.3	1.4	6.5	6.2
Cow	2.6	2.9	1.1	1.1	1.2	1.5	1.7	1.3	0.9	0.9	1.0	1.3	5.8	6.1
Breed														
Guernsey	2.6	2.8	0.9	0.9	1.4	1.4	2.2	1.3	0.8	0.9	1.2	1.4	6.5	5.9
Holstein	2.6	2.8	1.1	1.2	1.2	1.6	1.6	1.3	0.9	1.0	1.1	1.4	5.8	6.4
Standard deviation of an animal	0.6	0.5	0.5	0.7	0.7	0.7	0.7	0.5	0.4	0.7	0.6	0.9	1.5	1.7

[a] The classes were arbitrarily assigned numerical values as follows: negative—0, slight—1, slight plus—2, distinct—3, distinct plus—4, marked—5 with an additional ½ or 1 added for slight or marked atrophy, respectively.

[b] The criteria for teat-end scores were assigned values as follows: negative—0, slight—1, severe—2,

observed in the percentage of milk samples free from mastitis organisms or the number of clinical cases to substantiate the report by Dodd *et al. (4)*. There are several possible explanations for the failure in this and prior experiments to observe clinical responses similar to those reported by the Reading workers in heifers milked for an 8-minute duration over the entire lactation. First, less precaution against transfer of mastitis organisms (teat cup rinse between cows, milking infected cows after clean ones, etc.) was taken by Dodd *et al.* than in the investigations conducted at the Storrs Station. Secondly, all cows in this herd have been free from *S. agalactiae* for a period of years, including those during which these investigations were carried out. This organism is known to be the most common cause of chronic mastitis in herds where its eradication has not been undertaken *(2, 8, 11)*. Further, these trials were carried out under the environmental conditions existing in only one herd, whereas the report by the Reading workers covered several herds. In addition, the number of animals (replicates) used in the Storrs trial was more limited. The source of animals, however, was not as restricted as the one herd might indicate, since a considerable number of the experimental animals were purchased from other herds.

It should be emphasized that the irritation to the udder tissue due to excessive milking duration, as reported in these studies, might have resulted in a more drastic response if carried out in herds where *S. agalactiae* was present and/or poor sanitation and mastitis control practices were employed. Since removal of the machine as soon as milking is complete is compatible with economical milking procedures, it becomes apparent that excessive milking durations should not be tolerated.

The occurrence of clinical mastitis which could not be attributed to improper milking practices should divert attention from the role of mechanical milking to more basic causes of mastitis. Among other important factors which need further elucidation are: antibacterial properties of the milk, tissue sensitivity, teat patency, individual cow susceptibility, and hereditary factors.

SUMMARY

Forty-eight animals, after a 4-week standardizing period immediately after calving, were assigned to be milked from the 5th to the 44th week of lactation at either 10, 13.5, or 17 in. of vacuum and for a "normal" or "twice normal" duration. Of these animals, 24 were Guernseys and 24 were Holsteins. Within each breed group, 12 were first-calf heifers and 12 had one or more previous lactations. Within each breed-lactation group of 12, six were selected for being "clean" of mastitis and six for being "infected." The latter was based on the occurrence of a clinical case of mastitis and/or the occurrence of more than 500,000 leucocytes per milliliter of milk and/or the presence of mastitis organisms in the milk during the standardizing period. The following results were observed:

1. Animals milked at 13.5 in. of vacuum had greater weekly increases in chloride content of the milk than did those milked at 10 and 17 in. No effect of vacuum level on any of the other criteria studied could be ascertained.

2. Twice normal milking duration resulted in greater positive weekly changes in leucocyte number and chloride content of milk than did the normal milking duration.
3. Animals classified clean with respect to mastitis and first-calf heifers had fewer leucocytes, less pronounced weekly rates of increase in leucocytes, greater percentages of milk samples free of mastitis organisms and lower udder fibrosis scores than did animals classified infected and those with one or more previous lactations, respectively.
4. Holsteins in this experiment had on the average a higher chloride content in their milk samples than did Guernseys.
5. Teat-end morphology as indicated by scores had a tendency to change with an increase in vacuum level and milking duration; however, the differences in the scores were found not to be statistically significant.

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EFFECTS OF VACUUM LEVEL AND MILKING DURATION ON GUERNSEYS AND HOLSTEINS DIFFERING WITH RESPECT TO LACTATION NUMBER AND STATUS OF UDDER HEALTH.

II. MILK YIELD, MILKING TIME, AND RATE OF MILK FLOW[1]

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Although considerable data from studies of short duration indicated factors in the operation of milking machines which affected rate of milking *(1, 3, 7, 12, 16, 17)*, there was a paucity of information as to how these factors influenced milk yield and rate of milking over an entire lactation. In mastitis-free first-calf heifers milked at vacuum levels of 10, 13, or 17 in. of mercury for a 40-week period, no appreciable differences in milk yield were observed *(10)*. However, with an increase in vacuum level, milking time decreased and rate of flow increased. The time spent in stripping and the amount of strippings, the latter expressed as a percentage of total yield, appeared to be least for the 13 in. group; whereas time to reach peak rate of flow was not significantly affected.

Milking first-calf heifers for an 8-minute duration over a 305-day lactation period resulted in a greater fat percentage in the milk than that of heifers milked for a 4-minute duration *(6)*. Halves of udders of mastitis-free first-calf heifers milked for a "twice normal" duration gave greater milk yields than those halves milked for a "normal" duration *(10)*; however, no significant differences in fat percentage were observed. In the first of these studies *(6)*, milking rates were reported to be unaffected by milking duration; whereas in the second *(10)*, faster average rates of flow were observed in the halves of udders milked for the twice normal duration.

The present project was undertaken to extend the information of the effects of vacuum level and milking duration on milk yield, milking time, and rate of milk flow, over an entire lactation, of Guernseys and Holsteins differing with respect to number of lactations and status of udder health.

EXPERIMENTAL PROCEDURE

Animals and feeding. Forty-eight animals from the University of Connecticut herd (*Streptococcus agalactiae*–free) were placed on experiment from August,

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1952, through July, 1953. Of these, 24 were Guernseys and 24 were Holsteins. Within each breed group, 12 were first-calf heifers and 12 were in their second or subsequent lactation. Within each breed-lactation sub-group of 12, six were selected for being mastitis "infected" and six for being mastitis "clean." Selection was made during the standardizing period, which consisted of the first 4-weeks of lactation. During this period, all animals were milked at 13.5 in. of vacuum for a minimum duration determined by the milking machine operator.

At the beginning of the fifth week post-calving, the six animals within each breed, lactation, and mastitis grouping were randomly assigned to be milked at one of three vacuum levels, 10, 13.5, and 17 in. of mercury, and for a normal or twice normal milking duration. Normal duration was defined as the period of time from attaching the milking machine to the udder until the rate of flow dropped to 0.2 lb. or less for a 15-second interval *(1)*. Twice normal was twice the normal duration for the particular animal concerned. The milking duration for each cow was determined the last day of the standardizing period and adjusted at 4-week intervals thereafter. The animals were milked at their assigned milking treatments from the fifth through the 44th week of lactation (or until dry), the comparison period. Milking was carried out with upright claw-type milkers operating at 48 to 50 pulsations per minute. Vacuum and rate of pulsation were checked weekly.

Details of the selection, management, and feeding of the animals are contained in the previous paper *(14)*, which reported the effects of vacuum level and milking duration on udder health.

Criteria and analyses. Milk yields were recorded to the nearest 0.1 lb. daily at the morning and evening milking. Two-day aliquot milk samples were obtained from each cow for fat determination by a modified Babcock procedure *(18)* during the fourth week of the standardizing period and during the middle of each consecutive 4-week interval of the comparison period. The amount of fat-corrected milk (FCM) was calculated from Gaines' formula *(9)*.

Milking time was defined as the period from the application of the teat cups until the rate of milk flow decreased to 0.2 lb. or less for a 15-second interval (similar to normal duration). It was determined by hanging the milker unit from a suspended Toledo scale (Model 1001) and recording its weight to the nearest 0.1 lb. at successive 15-second intervals. Stripping time, during which the milking machine operator applied downward pressure on the teat cup claw as well as downward massaging of the udder, was the period from the completion of normal or twice normal milking time to termination at the operator's discretion. Both milking time and stripping time were determined at the morning and evening milkings on the last day of the standardizing period and on the first day of each cow's successive 4-week interval during the comparison period. Thus each cow had a total of 10 daily observations for the comparison period. The amount of strippings expressed as a percentage of the total pounds of milk also was determined at the same intervals.

Average rates of flow for the interquartile range, the middle half of the milking period, and for the entire range were calculated from milk weights

recorded at successive 15-second intervals during the determination of milking time. Time to reach peak rate of flow was defined as the time from the application of the teat cups to the first 15-second interval during which maximum milk yield was obtained.

The statistical analyses were similar to those previously described *(14)*. Time trends of the various response criteria over the 40-week comparison period were explored. However, only the linear trends are reported herein because of the relatively small contribution to the total sums of squares of higher order trends. Adjustment of the comparison period values for those of the standardizing period was made by the method of covariance when accounting for a significant reduction ($P < 0.05$) in the error variability.

RESULTS

Milk production. Average daily pounds of milk, fat, and FCM, as well as fat percentage, are given in Table 1. Animals milked at the 13.5 in. vacuum level produced milk of slightly lower percentage fat and fewer pounds of fat ($P < 0.10$) than did animals milked at either the 10 or 17 in. vacuum level; however, no statistical differences were observed when the milk yields were equated to FCM. The response to vacuum levels was not consistent across infection and lactation classifications. For animals classified clean, the 13.5 in. vacuum level resulted in the greatest milk production; whereas for animals classified infected the 13.5 in. vacuum level resulted in the lowest milk production ($P < 0.01$). Similarly, heifers produced more milk on the 13.5 vacuum level; whereas cows produced the least amount of milk at this vacuum level ($P < 0.01$). The time trends (Table 1), expressed as rate of change per 4-week period, followed essentially the same pattern as the average responses.

Animals milked for the twice normal duration showed a slight advantage in pounds of milk and pounds of fat produced over animals milked for the normal duration. Although the fat percentage of milk from the twice normal animals was slightly lower, an apparent increase in FCM production resulted. It was of interest that Holsteins, in this experiment, milked for the twice normal duration yielded considerably more pounds of milk, fat, and FCM than those milked for the normal duration, whereas the opposite was true for the Guernseys ($P < 0.01$).

Animals classified mastitis clean, first-calf heifers and Guernseys gave fewer pounds of milk, fat, and FCM than did those classified mastitis infected, cows, and Holsteins.

Milking time and machine stripping. The average total time per cow per day spent in milking and stripping and amount of strippings expressed as a percentage of the total yield of milk are presented in Table 2. Although the average time spent in milking decreased in a linear manner with an increase in vacuum level ($P < 0.05$), such a relationship was not found for stripping time and amount of strippings. As was expected because of the individuality of cows with respect to milking and stripping time, the values observed during the comparison period were correlated with those of the standardizing period. This

TABLE 1

The effect of vacuum level, milking duration, degree of infection, lactation, and breed on milk production

Experimental classification	Milk yield			Per cent of fat			Fat yield			Fat-corrected milk (FCM)		
	Standardizing period	Comparison period		Standardizing period	Comparison period		Standardizing period	Comparison period		Standardizing period	Comparison period	
	Av.	Av.	Linear rate of change per 4 wk.	Av.	Av.	Linear rate of change per 4 wk.	Av.	Av.	Linear rate of change per 4 wk.	Av.	Av.	Linear rate of change per 4 wk.
	(lb/cow/day)			*(%/cow)*			*(lb/cow/day)*			*(lb/cow/day)*		
Vacuum level												
10 in.	43.1	28.2	−2.493	4.2	4.4	+0.078	1.782	1.184	−0.094	44.0	29.0	−2.412
13.5 in.	42.9	28.9	−3.159	4.1	4.3	+0.073	1.756	1.158	−0.116	43.5	28.8	−2.998
17 in.	42.6	28.8	−2.810	4.2	4.5	+0.073	1.784	1.233	−0.107	43.8	30.1	−2.729
Milking duration												
Normal	42.5	27.6	−2.767	4.2	4.4	+0.062	1.786	1.178	−0.109	43.8	28.8	−2.749
Twice normal	43.2	29.6	−2.874	4.2	4.3	+0.087	1.762	1.204	−0.102	43.7	29.8	−2.677
Infection												
Clean	40.4	27.3	−2.871	4.1	4.4	+0.084	1.651	1.131	−0.105	40.9	27.9	−2.724
Infected	45.3	29.9	−2.770	4.3	4.4	+0.065	1.898	1.252	−0.106	46.6	30.7	−2.702
Lactation												
Heifer	36.7	25.6	−1.898	4.2	4.4	+0.067	1.521	1.092	−0.068	37.5	26.6	−1.773
Cow	49.0	31.6	−3.743	4.2	4.3	+0.082	2.027	1.291	−0.144	50.0	32.0	−3.653
Breed												
Guernsey	36.0	22.2	−2.283	4.5	4.9	+0.089	1.607	1.063	−0.094	38.5	24.8	−2.322
Holstein	49.7	35.0	−3.358	3.9	3.9	+0.060	1.942	1.320	−0.117	49.0	33.8	−3.104
Standard deviation of an animal	5.6	2.7	1.230	0.4	0.3	0.075	0.230	0.081	0.053	5.4	2.1	1.270

TABLE 2

The effect of vacuum level, milking duration, degree of infection, lactation, and breed on milking time and machine stripping

Experimental classification	Milking time[a]			Stripping time[b]			Amount of strippings[c]		
	Standardizing period	Comparison period		Standardizing period	Comparison period		Standardizing period	Comparison period	
	Av.	Av.	Linear rate of change per 4 wk.	Av.	Av.	Linear rate of change per 4 wk.	Av.	Av.	Linear rate of change per 4 wk.
	(sec/cow/day)						*(% of total yield)*		
Vacuum level									
10 in.	623	561	−38.08	109	110	+2.86	6.3	12.8	+1.08
13.5 in.	593	432	−33.56	170	138	+2.16	8.8	16.7	+2.80
17 in.	610	367	−30.97	175	146	+2.80	7.7	16.0	+2.21
Milking duration									
Normal	609	461	−35.73	175	154	+2.27	8.8	14.9	+2.13
Twice normal	609	445	−32.67	128	109	+2.95	6.4	15.5	+1.93
Infection									
Clean	599	447	−35.44	116	120	+2.92	5.8	14.8	+2.21
Infected	619	460	−32.97	186	143	+2.30	9.4	15.6	+1.85
Lactation									
Heifer	641	471	−32.15	162	126	+2.28	8.2	13.9	+1.19
Cow	578	435	−36.25	141	137	+2.94	7.0	16.4	+2.87
Breed									
Guernsey	544	401	−31.98	144	134	+2.67	8.5	18.0	+2.57
Holstein	674	505	−36.42	159	129	+2.55	6.7	12.3	+1.49
Standard deviation of an animal	232	149	20.14	61	59	4.07	2.9	5.4	1.51

[a] Milking time = sum of the A.M. and P.M. determinations of the time from the application of the teat cups until the rate of milk flow decreased to 0.2 lb. or less for a 15-second interval.

[b] Stripping time = sum of the A.M. and P.M. determinations of the time from the completion of normal or twice normal milking times, during which the milking machine operator applied downward pressure on the teat claw as well as downward massaging of the udder to termination at operator's discretion.

[c] Amount of stripping = [(Sum of the A.M. and P.M. determinations of the lb. of milk obtained during stripping time) (100)]/[Sum of A.M. and P.M. determinations of the total lb. of milk].

allowed adjustment of the comparison period values for those of the standardizing period. These adjusted values in seconds per cow per day were for average milking time 552, 441, and 367 ($P < 0.001$) and for stripping time 136, 126, and 132, respectively, for the 10, 13.5, and 17 in. vacuum levels. The least amount of time spent in stripping (adjusted values) was for the animals milked at the 13.5 in. vacuum level; however, the differences did not approach statistical significance. The amount of strippings was least for the animals milked at the 10 in. vacuum level ($P < 0.05$). These results of milking time with respect to vacuum level appeared to be fairly consistent across mastitis, lactation, and breed classifications. However, the decrease in milking time with an increase in vacuum level was considerably less for animals milked for the twice normal duration than those milked for the normal duration ($P < 0.05$). In the former group there was little difference between the 13.5 and 17 in. vacuum levels.

Animals milked for the twice normal duration required less time for stripping than did those milked for the normal duration ($P < 0.05$). There were inappreciable differences in milking and stripping times and amount of strippings within infection and lactation classifications. However, Guernseys required less time to milk than did Holsteins; this probably was due, in part, to the smaller milk yield of the Guernseys.

On the average, total daily milking time (Table 2) decreased at a rate of 34 seconds per 4-week interval over the lactation, and the amount of strippings increased by 2% per 4-week period. The rate of change for stripping time was not appreciable.

Rates of milk flow. In Table 3 are presented the average rates of flow in pounds of milk per cow per 15-second interval for the interquartile range, the entire milking interval, and the average seconds per cow per day to reach peak rate of flow. Average rates of flow, both interquartile range and entire range values, increased linearly with an increase in vacuum level ($P < 0.05$); time to reach peak rate of flow decreased ($P < 0.05$). Comparison period averages adjusted for the values observed during the standardizing period for the 10, 13.5, and 17 in. vacuum levels were, respectively, 0.9, 1.0, and 1.3 lb. per 15-second interval for the interquartile range rates of flow ($P < 0.001$); 0.8, 0.9, and 1.2 for the entire range rates of flow ($P < 0.001$); and 204, 152, and 125 seconds for the time to reach peak rate of flow ($P < 0.01$). The response of the average rates of flow to an increase in vacuum level was considerably less in heifers than in cows ($P < 0.05$ for the adjusted values). Also, animals milked at the twice normal duration responded to a lesser degree than did those milked for the normal duration ($P < 0.05$). Milking duration was without appreciable effect on milking rates or time to reach peak rate of flow.

Guernseys milked at slower average rates than did Holsteins ($P < 0.01$) and heifers slower than cows ($P < 0.01$ for entire range; $P < 0.05$ for interquartile range). The difference between breeds was not accounted for by adjustment of comparison period values for those of the standardizing period ($P < 0.05$ for entire range and $P < 0.01$ for interquartile range); whereas the difference between heifers and cows was accounted for. Guernseys required less time to

TABLE 3

The effect of vacuum level, milking duration, degree of infection, lactation, and breed on rates of milk flow

Experimental classification	Rate of flow (interquartile range) [a]			Rate of flow (entire range) [b]			Time to reach peak rate of flow [c]		
	Standardizing period	Comparison period		Standardizing period	Comparison period		Standardizing period	Comparison period	
	Av.	Av.	Linear rate of change per 4 wk.	Av.	Av.	Linear rate of change per 4 wk.	Av.	Av.	Linear rate of change per 4 wk.
	(lb/cow/15 sec.)						*(sec/cow/day)*		
Vacuum level									
10 in.	1.2	0.9	−0.027	1.1	0.8	−0.021	221	201	−18.61
13.5 in.	1.3	1.1	−0.076	1.1	0.9	−0.055	248	155	−15.64
17 in.	1.2	1.3	−0.046	1.0	1.1	−0.037	242	126	−10.82
Milking duration									
Normal	1.2	1.1	−0.051	1.0	0.9	−0.039	252	168	−16.80
Twice normal	1.2	1.1	−0.048	1.1	1.0	−0.037	222	153	−13.24
Infection									
Clean	1.3	1.1	−0.054	1.1	1.0	−0.042	269	177	−17.38
Infected	1.2	1.0	−0.045	1.0	0.9	−0.034	206	144	−12.67
Lactation									
Heifer	1.0	1.0	−0.017	0.9	0.8	−0.012	260	179	−15.87
Cow	1.5	1.2	−0.082	1.2	1.0	−0.063	215	142	−14.18
Breed									
Guernsey	1.1	0.9	−0.053	0.9	0.8	−0.041	201	137	−12.42
Holstein	1.4	1.3	−0.046	1.2	1.1	−0.035	274	184	−17.63
Standard deviation of an animal	0.4	0.3	0.060	0.3	0.2	0.042	171	61	11.17

[a] Rate of flow during interquartile range = av. of the A.M. and P.M. determination of $\left[\frac{\text{milk production (lb.) during middle half of the milking period}}{\frac{1}{2}\text{ (No. of 15-sec. intervals during milking period)}}\right]$.

[b] Rate of flow for entire range = av. of A.M. and P.M. determination of $\left[\frac{\text{milk production (lb.) during the milking period}}{\text{No. of 15-sec. intervals during the milking period}}\right]$.

[c] Time to reach peak rate of flow = sum of the A.M. and P.M. determinations of the time from the application of the teat cups to the first 15-second interval during which maximum yield was obtained.

reach peak rate of flow than did Holsteins ($P < 0.05$), and this difference apparently remained after adjustment ($P < 0.10$).

The average linear rates of change per 4-week period (Table 3) were inappreciable with regard to rates of milking; however, they were of considerable magnitude for time to reach peak rate of flow and in general followed the same trends as the averages.

DISCUSSION

From the results of this experiment and the previous one *(10)* it seems reasonable to make the assumption that vacuum levels per se have no appreciable effect on milk production. This is particularly apparent when consideration is given to the inappreciable differences in FCM between vacuum levels.

Vacuum levels are of considerable influence in reducing milking time and time to reach peak rate of flow as well as increasing milking rates per unit of time. The results reported herein are similar to those obtained in short-time studies reported by Smith and Petersen *(16)* and Baxter *et al. (1)* and in a 40-week study of mastitis-free first-calf heifers *(10)* and extend these general findings to animals with more than one lactation and to animals clean and infected with mastitis.

It has been generally accepted that increasing the vacuum level results in increased stripping time and amount of strippings *(1, 16)*. This has been explained by greater teat cup crawling directly related to vacuum level, thereby obstructing or occluding the milk passageways at the base of the teat. Although the differences were of relatively small magnitude, the data from this study and the previous one *(10)* indicate that, for the milker unit used, a vacuum level of approximately 13 to 13.5 in. results in minimum stripping time. Therefore, it might be considered that insufficient vacuum was present to remove all the milk from some of the animals milked at the 10 in. level. This, of course, applied only to the particular milker unit used in this study, and it indicated that each particular milker unit may have a unique vacuum level (or possibly a narrow range of levels) which results in minimum stripping time.

Leaving the milking machine on the udder for an extended duration resulted in slightly greater yields of FCM, 1.0 lb. per cow per day for this experiment and 1.2 lb. for the experiment previously reported *(10)*. Similarly, the time spent in stripping was less in both experiments, which was apparently due to the extra milk obtained during the period after normal milking. However, because of the possible irritation to the udder tissue *(14)* and the excessive chore time involved, this practice cannot be recommended.

The greater milk production and slower rates of milk flow of the animals classified infected with mastitis as compared to those classified clean are contrary to previous reports in the literature *(8, 11, 13)*. Two of these reports *(11, 13)* dealt with *Streptococcus agalactiae* infections, which were not present in the animals used in this study. However, in one of the previous reports *(8)* staphylococcus was the organism causing the majority of the new infections. Two possible explanations for the difference were *(a)* that the organisms present in this study,

mainly staphylococcus, failed to cause sufficient tissue damage to reduce milk yield during the experimental period or *(b)* that inherent differences existed in production and teat structure between the animals used in this experiment and those in the experiment of Dodd and Neave *(8)*. Clearly, additional information is needed on the causative mechanism of mastitis before such differences can be adequately explained.

The differences between animals in their first lactation (heifers) and those with one or more lactations (cows) and between breeds (Guernseys and Holsteins) were largely expected and agree essentially with previous work *(2, 4, 5)*.

It should be noted that the quantitative aspects of the results reported herein and those of others previously cited apply only to the particular milking machine under test. The recent report of Porter *et al. (15)*, in which two different machines were used, one designed to operate at 13.5 in. of vacuum and at 48 pulsations per minute and another at 10 in. of vacuum and 120 pulsations per minute, indicated that "either machine, when properly operated, did a good job of milking." However, in general the qualitative aspects of the results reported herein and those of others can be accepted. For example, it appears reasonable to assume that with an increase in vacuum, for any given machine, rate of milk flow will increase, but the magnitude of the increase will probably be characteristic of the particular machine.

SUMMARY

Forty-eight animals from a *Streptococcus agalactiae*–free herd, after a 4-week standardizing period immediately after calving, were assigned to be milked from the fifth to the 44th week of lactation at either 10, 13.5, or 17 in. of vacuum and for a "normal" or "twice normal" duration. Of these animals, 24 were Guernseys and 24 Holsteins. Within each breed group, 12 were first-calf heifers and 12 had one or more previous lactations. Within each breed-lactation group of 12, six were selected for being "clean" of mastitis and six for being "infected." The following results were obtained:

1. No appreciable differences in milk yield and FCM were observed between vacuum levels. Milking time and time to reach peak rate of flow decreased in a linear manner and rate of milk flow increased. The least amount of time spent in stripping was at the 13.5 in. vacuum level, and the least amount of strippings, expressed as a percentage of the total yield, was at the 10-in. level.
2. Leaving the milking machine on the udder for an extended duration (twice normal) resulted in slightly greater yields of FCM (1.0 lb. per cow per day) and decreased stripping time.
3. In this experiment, mastitis infected animals gave greater milk yields and had slower rates of milk flow than did the mastitis clean animals.
4. The differences between first-calf heifers and animals with one or more lactations and between Guernseys and Holsteins agreed in general with previously published studies.

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PEOPLE and EVENTS
in the Dairy Science World

IAMFS Names Officers and Presents Awards

H. S. ADAMS, Indianapolis, was formally installed as president of Intern. Assoc. of Milk and Food Sanitarians as some 300 participants from the United States and Canada brought their 42nd Annual Meeting to a close Oct. 6 at the Bon Air Hotel in Augusta, Ga. He succeeds IVAN PARKIN of Pennsylvania Park, Pa. PAUL CORASH, New York City, was named president-elect. Other officers elected were: W. A. HOSKISSON, supt. of sanitation and quality, Arden Sunfreze Creameries, Salt Lake City, first vice-president; H. B. ROBINSON, Milk and Food Program, U. S. Public Health Service, Washington, D. C., second vice-president; and H. H. WILKOWSKE, Gainesville, Fla., secretary-treasurer.

Two sanitarians—one a city health department employe and the other a veteran of the U. S. Public Health Service—were honored with citation awards at the banquet of the IAMFS. Receiving the awards were R. G. Ross, chief milk sanitarian of the Tulsa, Oklahoma, City-County Health Department, and A. W. FUCHS, long-time top adminstrator of the milk and food program of the U. S. Public Health Service and currently serving in Jamaica with the Intern. Cooperation Admin. as adviser on environmental sanitation problems.

Dr. Ross served as president of the Association in 1947, and has been active on numerous important IAMFS committees. In addition, he served on the Special Committee to the Dairy Branch of the War Production Board during World War II. He was for several terms auditor of the Association.

Mr. Fuchs joined IAMFS in 1928 and became its president in 1949. He served on the Executive Board for 6 years. He has served as chairman of the Advisory Committee to The War Production Board and has been active on committees dealing with sanitary procedure, milk regulations and ordinances, and communicable diseases. He has been associate editor of the *Journal of Milk and Food Technology* since 1947 and has contributed numerous papers to that journal. Mr. Fuchs also was active in bringing about the participation of IAMFS and the U. S. Public Health Service with proper dairy industry bodies in the formation of 3-A Sanitary Standards for Dairy Equipment and in establishing standards for other food equipment. The Citation Awards were presented by J. D. FAULKNER, chairman of the IAMFS Committee on Recognition and Awards.

B. G. TENNANT, chief sanitarian of the Escambia County Health Dept., Pensacola, Fla., received the Sanitarian's Award for the most meritorious contribution to the health and welfare of his community in the past 5 years. The award carries with it a check for $1,000. This presentation also was made at the 42nd annual banquet of the IAMFS. Administered by IAMFS, and presented annually only to municipal or county sanitarians, this award is the highest national recognition bestowed upon professional local sanitarians.

The award is sponsored by five companies: Diversey Corp., Klenzade Products, Inc., Oakite Products, Inc., Olin Mathieson Chemical Corp., and the Pennsylvania Salt Manufacturing Co. The firms, however, have no voice in selecting recipients.

F. F. Hill Assumes Ford Foundation Vice-Presidency

F. F. HILL, former governor of the Farm Credit Admin. and recently provost of Cornell Univ., has assumed office as vice-president of the Ford Foundation. He will have particular responsibility for the Foundation's efforts to assist countries in Asia and the Near East raise their standards of living and learning. Dr. Hill is a member of the Board of Governors of the Federal Reserve Bank of New York. Since his service with the Farm Credit Admin. he has also aided the government as a consultant to the Economic Cooperation Admin.

At Cornell, Dr. Hill has been professor of land economics, head of the Dept. of Agricultural Economics, and provost. He has served also as president of the American Farm Economics Assoc., as a director of the Center for Advanced Study in the Behavioral Sciences, and as a member of the National Planning Assoc. Committee which studied technical assistance in Latin America.

Conferences to Be Held

The 5th Annual Dairy Industry Conference sponsored by the Dept. of Dairy Science at the Univ. of Arizona will be held Jan. 25 and 26, 1956. Guest speakers will include H. C. OLSON, Dept. of Dairying, Oklahoma A. & M.; MORRIS HITE, Tracy-Locke Co., Dallas, Tex.; M. E. POWELL, Knudsen Creamery Co., Los

Angeles; and J. H. STEELE, chief, Veterinary Public Health, U. S. Public Health Service.

Michigan State Univ. will hold its 4th Annual National Dairy Engineering Conference March 13 and 14, 1956, at the Kellogg Center, East Lansing. Proceedings of the meeting will be supplied all those who attend.

News from Louisiana

W. S. GRIFFITH, former research associate at the Louisiana State Univ., has accepted an appointment as assistant professor and assistant dairy husbandman in the Virginia Agricultural Extension Service at Blacksburg. He received the B.S. degree in dairy husbandry at Penn State in 1953 and the M.S. degree in dairy production at L.S.U.

B. B. JONES, long a prominent figure in Louisiana agriculture, retired as Orleans Parish agent recently. As a leader in many statewide projects as well as a county agent, he was able to do much for the advancement of dairying. Probably his greatest contribution was the part he took in organizing the Tick Eradication Committee. He campaigned throughout the state for the legislative measures necessary to carry out this work and assisted in the drafting of many dairy laws. He also served as secretary-treasurer of the Louisiana Jersey Cattle and Dairy Assoc. and as co-editor of the *Louisiana Dairyman*.

. His county agent work extended beyond the state of Louisiana, placing him on several committees of the National Assoc. of County Agents. He issued a weekly newsletter and carried on a radio program of timely agricultural news. Mr. Jones retired to a small farm near Denham Springs, La.

Twelve graduate students are enrolled in the Louisiana State Univ. Dairy Department, representing schools in Louisiana, Oklahoma, Arkansas, Tennessee, Puerto Rico, and Venezuela.

At least 10% increase in Louisiana dairy production is expected during the next year as a result of the high yield of the feed crops: corn, oats, and hay. There is approximately 15% more home-grown dairy cattle feed in the state than normally.

The Louisiana average blend price for milk in August was $5.34 per hundredweight for 4% milk. Class I price during October for the New Orleans milk shed was $6.37.

Dairy Industry to Have Exhibit at International Trade Fair

Arrangements are being completed for the first educational exhibit of milk and dairy products at an international trade fair. Developed by Dairy Industries Society, International, as part of its program to promote the use of milk and dairy products in all parts of the globe, this exhibit, to be staged at the International Trade Fair in Bogota, Colombia, Nov. 25 to Dec. 11, is the result of cooperation between industry, as represented by DISI, and the U. S. and Colombian governments.

The dairy display will include nearly all types of dairy products and will tell the story of milk's benefits in both display materials and printed leaflets. A special feature will be a demonstration of continuous ice cream making and of the recombining of dry milk solids and anhydrous butterfat into beverage milk. Samples of each of the products will be dispensed, and it is expected that there will be special demonstrations for teachers, medical and welfare officials, parents' organizations, etc. Attendance at the Bogota Fair is expected to run to a million and a half.

Much of the equipment for the recombining demonstration and for the ice cream making, as well as the paper cups, has been donated or loaned by U. S. dairy equipment and supply manufacturers. The U. S. National Dairy Council, under the direction of its president, MILTON HULT, is cooperating in the preparation of the educational materials to be distributed at the Fair. Dairy products for the demonstrations are being furnished through the Commodity Credit Corp. of the USDA.

Ohio State News

L. H. BURGWALD, who has been on leave from the Dept. of Dairy Technology, has announced his plans to retire from the University and to devote his full time to his assignment with the Foreign Agricultural Service. Professor Burgwald earned his B.S. degree at Ohio State in 1914 and his M.S. degree at the Univ. of Wisconsin in 1941. Immediately after graduating in 1914, Burgwald became manager of the Moraine Dairy at Dayton, Ohio. In 1917 he transferred to the John Wilde Milk Condensing Co., Horsehead, N. Y., for a short time and then accepted a position with the USDA, where his main interests were in extension and research.

During his 25 years at Ohio State his main fields of teaching were in market milk, principles of dairy technology, and advanced testing. In addition, he has taught courses in cheesemaking, concentrated milk products, buttermaking, refrigeration, and the judging of dairy products. For 13 years at Ohio State he was coach of the dairy products judging team, and under his guidance Ohio State teams won the championship six times in the Intern. Students Dairy Products Judging Contests. Professor Burgwald was honored by his former students at the last annual Dairy Technology Conference. At that time they presented him

with an album of letters of appreciation and a complete photographic outfit.

In January, 1955, Professor Burgwald was granted a year's leave of absence to work as a marketing specialist with the Foreign Agricultural Service of the USDA. He has completed surveys in Japan, Hong Kong, India, Pakistan, Egypt, Italy, and England in order to establish outlets for surplus American dairy products.

EMMETT BASSETT has been appointed a research fellow in the Dept. of Dairy Technology. He is working toward his doctor's degree, having received a B.S. degree from Tuskegee Institute and a master's degree from the Univ. of Massachusetts. His field of research is in the lesser known flavor constituents of cheese.

MRS. JAN HUBER has been appointed to the post of assistant in the Dept. of Dairy Technology. She will assist in the cheese research project now under way. Mrs. Huber received a B.S. degree in dairy technology from Purdue Univ. in 1955.

DONALD VELL has enrolled in the graduate program of the Dept. of Dairy Technology, on a DISA scholarship from Kansas State College. He was a member of the judging team from Kansas that won honors at the 1954 student judging contest.

PALAMAND SURYANARAYAMA RAO of Bangalore, India, has enrolled in the graduate program of the Dept. of Dairy Technology. Mr. Rao's primary field of interest is in bacteriology. He received a bachelor's degree from the Univ. of Mysore and a master's degree from the Univ. of Bombay.

PRESIDENT H. L. BEVIS has announced that on June 30, 1956, he will retire as president of The Ohio State Univ. President Bevis assumed his present post in 1940, having served, prior to coming to Ohio State, as justice of the Ohio Supreme Court, two terms as state finance director, and as professor of business administration at Harvard Univ. During his term of office, Ohio State enrollment increased from 13,073 in 1940 to 25,400 in 1947 and is now 21,500.

Dean of the Graduate School, N. P. HUDSON, has tendered his resignation to the Board of Trustees. In his letter, Dean Hudson asked to be relieved of his administrative duties and be allowed to return to teaching and research in the Dept. of Bacteriology.

The Ohio Dairy Products Assoc. is undergoing a reorganization which will make it more effective and flexible. For purposes of representation on the Executive Board, the state has been divided into nine geographical sections, each of which will elect a chairman, a secretary, a member of the Ohio Ice Cream Division Board of Trustees, and a member of the Ohio Milk Distributors Board of Trustees.

Third International Congress on Animal Reproduction to Be Held

The 3rd Intern. Congress on Animal Reproduction (Physiology, Pathology, and Artificial Insemination) will be held in Cambridge June 26-30, 1956. The Congress is arranged by the Intern. Standing Committee on Physiology and Pathology of Animal Reproduction and of Artificial Insemination, of which the president is NILS LAGERLOF, Stockholm. Further, a United Kingdom Organizing Committee has been established with representatives from the Ministry of Agriculture, Fisheries and Food; the Milk Marketing Boards of England, Wales, and Scotland; the Agricultural Research Council; the Society of Animal Breeding; the British Society of Animal Reproduction; the British Veterinary Association; the Council of the Royal Agricultural Society of England; the National Farmers' Union; and the Veterinary School, Cambridge.

SIR THOMAS DALLING has accepted the presidency of the Congress at Cambridge, GEORGE GOULD is chairman of the Organizing Committee, and JOHN HAMMOND, F.R.S., is vice-chairman. The honorary secretary and treasurer is JOSEPH EDWARDS.

The following are the main topics to be discussed at the Congress: the physiology of prenatal life, genital infection, nutrition in relation to reproduction, the effect of very low temperatures (deep freeze) on cells and tissues, and recent advances in A. I. techniques and the study of animal behavior. Full details of the Congress may be obtained from the Honorary Secretary of the Organizing Committee, Milk Marketing Board, Thames Ditton, Surrey.

At the conclusion of the Congress, members will have an opportunity of visiting the Royal Show at Newcastle-on-Tyne. The Organizing Committee has the honor to invite all interested authorities and organizations to participate in this Congress, and it extends a particular welcome to scientists and technicians working in the field of animal reproduction. It would greatly assist the Organizing Committee if all those who are proposing to attend the Congress could inform the Secretary at the earliest opportunity.

Minnesota News Items

C. M. CLIFTON has joined the dairy husbandry staff as assistant professor. Dr. Clifton came to Minnesota from the Ohio State Univ. and is replacing N. D. BAYLEY, who is now with the U. S. Dept. of Agriculture at Beltsville, Md.

Another new assistant professor on the dairy husbandry staff is J. B. WILLIAMS, who came to Minnesota from the North Dakota Agricultural College.

A new position of dairy manufacturing extension specialist has been filled by J. H. GHOLSON, formerly of the Dairy Husbandry Dept. of the Univ. of Missouri.

P. J. DZIUK has left the Univ. of Minnesota to assume his new duties in the animal genetics section of the Animal Science Dept. of the Univ. of Illinois. He will work in the physiology of reproduction and genetics.

Eight students entering the Univ. of Minnesota have been picked as winners of the dairy industry scholarships, which are being awarded on the basis of academic and professional aptitude and character. Each scholarship amounts to $300 for the school year.

Oklahoma Team First at Kansas State Fair

Dairy cattle judging teams from Oklahoma, Iowa State, Missouri, South Dakota, Nebraska, Kansas, and Arkansas competed in the 3rd Intercollegiate Dairy Cattle Judging Contest held at the Kansas State Fair in Hutchison, Sept. 19. The high team trophy went to the Oklahoma A. & M. team, coached by P. C. MCGILLIARD. High man in the contest was E. S. HOWARD, JR., of the Univ. of Missouri.

News of Iowa State College

LON MCGILLIARD, former associate professor of dairy husbandry at Iowa State College, has joined the Dairy Dept. staff at Michigan State Univ. as associate professor.

LANTIS RATCLIFF, formerly assistant professor in dairy husbandry at the Univ. of Arkansas, has joined the Dairy Husbandry staff at Iowa State College as research associate.

ERLING BRANDSAETER, who received his Ph.D. in dairy bacteriology at Iowa State College in August, has returned to his position in the Dairy Dept. at the Agricultural College of Norway at Vollebekk.

SOLOMON BLOOM, who recently received his Ph.D. degree in dairy husbandry at Iowa State College, has accepted a position as animal nutritionist in the Animal Husbandry Dept. at the Univ. of Puerto Rico, Rio Piedras, P. R.

D. A. MCKENZIE, head of the Agricultural Bacteriology Dept. at the North of Scotland Agricultural College, Aberdeen, is spending 2 months as a visiting professor in the Dairy Industry Dept. at Iowa State College. He is the recipient of an Intern. Fellowship from the M. W. Kellogg Foundation. Before returning to Scotland in December, he will visit several other laboratories in the United States.

T. W. HOLZINGER, who received his M.S. degree in dairy bacteriology at Iowa State in December, 1954, has left the Univ. of Vermont to take a position with the New Jersey Dairy Laboratories, New Brunswick.

On November 4 and 5 the Dairy Industry Club of Iowa State College took a 2-day field trip by chartered bus to Minneapolis and St. Paul. Outstanding dairy processing plants in northern Iowa and southern Minnesota were visited. About 60 students made the trip.

Alumni and other friends of the late DR. M. MORTENSEN, for many years head of the Dairy Industry Dept. at Iowa State College, have made available to freshman students in dairy industry several scholarships of $300 each, beginning with the fall quarter of 1956. Since the donors reside in all parts of the U. S. and other countries, the awarding of these scholarships will not be limited to residents of Iowa.

Dairy Mergers

The National Dairy Products Corp. has acquired Bedford Products, Inc., manufacturers of jams, jellies, and frozen fruit concentrates. The company does an annual business of over 5 million dollars.

The Borden Co. has taken over the F. H. Soldwedel Co., in Pekin, Ill. The company was started by the grandfather of the present president, Tim Soldwedel, 75 years ago. The Soldwedel company is processor and distributor of market milk, condensed milk, and ice cream.

The Fergus Cooperative Creamery (Fergus Falls, Minn.) and the Fergus Dairy Cooperative have merged. The joint operation will be under the supervision of L. M. HYSELL.

Foremost Dairies, Inc., have acquired the assets and business of the Western Condensing Co. of Petaluma, Calif. The acquired company produces products used in the manufacture of feeds for poultry and livestock, drugs, and infant foods. It operates 37 plants and does an annual business of over 14 million dollars.

The Fairmont Foods Co. of Parkersville, W. Va., has purchased the Beckley Ice Cream Co., of Beckley, W. Va.

Scientific Papers Invited for International Dairy Congress

United States scientific and technical workers in the field of dairy science have been invited to submit papers and to attend and take part in discussions of the various sectional meetings

of the Intern. Dairy Congress to be held in Rome, Italy, September 24-28, 1956.

The Congress is under the direction of the Intern. Dairy Federation. The Italian National Committee, with approval of the Italian government, is organizing the 1956 sessions. Secretary general of the Congress is G. PITTONI, via Guidubaldo del Monte, 24 Rome, Italy.

Arrangements for United States partcipation in the Congress are being handled by a committee of specialists in the U. S. Dept. of Agriculture, and technical papers should be submitted through this committee. Chairman of the committee is R. E. HODGSON, chief of the Dairy Husbandry Research Branch of the Agricultural Research Service, Beltsville, Md. Other committee members are H. C. TRELOGAN, Agricultural Marketing Service; D. S. ANDERSON, Commodity Stabilization Service; J. E. CROSBY, Federal Extension Service; DONALD HIRSCH, Farm Credit Administration; C. J. BABCOCK, Foreign Agricultural Service; and E. O. WHITTIER, Agricultural Research Service.

Dairy scientists desiring to propose papers for inclusion in the published proceedings of the Congress are requested to notify the U. S. committee chairman by Dec. 10, 1955, indicating the title and subject matter. Early notification of proposed papers is essential so that the secretary general can be notified to include them on the official program. Length of papers is limited to 2,000 words. All manuscripts are to be submitted in finished form before Feb. 25, 1956.

Sections listed under the scientific program of the Congress include: milk for liquid consumption; dairy products technical and economic problems; and legislation, control, and methods of analysis for dairy products. Conferences at the Congress also will be devoted to the position of the milk industry in the national economy; the provision in hot countries of a sufficient supply of milk; and effective and controlled use of surplus dairy products.

In addition to the formal program, a number of official tours and exhibitions are being arranged for participating scientists following the Congress.

Personal Notes

R. N. DOETSCH, associate professor of bacteriology at the Univ. of Maryland, has been named a Fellow of the John Simon Guggenheim Memorial Foundation for 1956. He will work on problems in rumen microbiology with DR. A. E. OXFORD of the Rowett Research Institute, Bucksburn, Aberdeenshire, Scotland.

K. L. TURK, head of the Dept. of Animal Husbandry at Cornell Univ., has returned from the Philippines, where he was stationed at the University. His assignment was under the Foreign Operations Admin. (now ICA). His work consisted essentially of helping organize and develop the experiment station.

J. C. WHITE, professor of dairy industry, Cornell Univ., has recently returned from a sabbatical leave spent in Colorado. Dr. White made a study of milk production methods in the Rocky Mountain region under the sponsorship of the Colorado Milk Producers and the Federal Marketing Service.

R. E. WARD has been named secretary-treasurer of the Eastern Section of A.D.S.A. for the coming year. Other officers are G. W. TRIMBERGER, chairman, and H. L. WILDASIN, vice-chairman.

I. I. LITMAN, food chemist, has joined the staff of the Dept. of Dairy Industry on the Davis campus of the Univ. of California. Appointed as junior research chemist, Litman will conduct experiments on oxidized flavors of milk. This continues and expands a program of study under the direction of W. L. DUNKLEY, associate professor of dairy industry.

A graduate of the Univ. of Massachusetts in 1949, Litman recently received a Ph.D. degree in food technology at the State College of Washington, Pullman. While studying for that degree he held a research assistantship for studies on powdered whole milk.

Why Has Farm Income Slipped While Cities Prosper?

Many farmers have asked, "Why has farm income gone down while the income of most other groups has gone up?" "This is an important question, and it deserves an honest answer," says L. H. SIMERL, Dept. of Agricultural Economics, Univ. of Illinois. As a first step in answering this question he presents three facts about farm and nonfarm incomes:

1. In a general way the incomes of farmers and nonfarmers tend to rise and fall together. During severe depressions, such as the 1930's, both farmers and nonfarmers suffer. During wars and other inflationary times, farmers and most other groups enjoy increasing incomes. For example, from 1929, a year of general prosperity, to 1932, a year of severe depression, farmers' cash receipts dropped 58%, the incomes of industrial workers dropped 56%, and corporate profits changed to losses. From 1940 to 1952, cash farm receipts increased 300%, the income of industrial workers went up 270%, and profits went up about 300%.

2. The second basic fact about the relation of farm income to the income of other groups is that during an inflation the net incomes of farmers go up much faster than the incomes of most other people. Then, later on, farmers lose their temporary advantage.

In 1940 gross farm income was 10.9 billion dollars and production expenses were 6.6 billion, leaving an operators' net income of 4.3 billion dollars. By 1947, gross income was 34.0 billion dollars, expenses 17.2 billion, and net income 16.8 billion. Thus, production expenses went up 163%, gross income climbed 212%, and net cash income ran up 290%. During this time the average annual income of the employed industrial worker went up only 97%.

After 1947, wages in industry began to catch up with the procession of inflation. Rising wages and other costs increased marketing margins, leaving a smaller and smaller share of the consumer's dollar for the farmer. Then, too, rising wages increased the costs of machinery, fuel, and other things that farmers require in operating their farms. And, finally, higher pay for industrial workers boosted farm living costs so that each dollar of the declining net farm income buys less than it did in the years before 1950.

3. In the long run still another fact prevents farm income as a whole from advancing as fast as total nonfarm income. That is the trend toward industrialization. During the past 200 years an ever-increasing proportion of our people have been working in industry and commerce. At first their share of the national income was small. Now, as a larger share of workers are employed off farms, their share of the national income is increasing and the farm share is decreasing.

Completed Theses

M.S.A. degree:

D. H. Bullock—Chromatographic studies on the progress of Cheddar cheese ripening. Ontario Agricultural College, Guelph, Ontario.

M.S. degree:

F. G. Owen—Growth and hematological response of calves to antibiotic and arsenical supplementation. Iowa State College.

Ph.D. degree:

Solomon Bloom—Effects of various dietary hay-concentrates ratios on nutrient utilization and production responses of dairy cows. Iowa State College.

Erling Brandsaeter—Proteolysis by *Lactobacillus casei*. Iowa State College.

H. H. Voelker—Physiological responses of dairy calves to ingestion of various antibiotics and surface-active agents. Iowa State College.

OUR ASSOCIATION

Our Industry Relations—Within and Without

Dear Fellow Members:

As we analyze our Association and plan for its future course, the question arises: "Is our organization serving all of its members and all of the industry, or is it limiting its efforts too largely to the academic field?"

Recently, some representatives of the commercial field have indicated that the philosophy and action of some of our own members and the lack of a positive approach on the part of our Association have contributed to the continuance of the belief in some circles that the Association is designed almost entirely for members of the staffs of universities and colleges. As examples, these men stressed the following: *(a)* "Only one man from the commercial industry (our secretary-treasurer, H. F. JUDKINS) has served as president of the Association;" *(b)* "far too few of those with commercial interests have been privileged to serve as directors;" *(c)* "the Association and Section committees are frequently disproportionately 'loaded' with men from the academic area;" *(d)* "in years past, the Journal has had too little of 'understandable' reading."

In their discussions, these men did not imply that the Association was not the important one for those of us in education and research. They think it is. The point they stressed was that the Association also is highly important and necessary for many others who are engaged in a wide variety of activities of a nonacademic nature, and these qualified persons should be encouraged to join and, as members, be requested personally to participate in the Association's activities.

These points in issue have been raised in good faith by men who are industry leaders and who are sincerely and vitally interested in the welfare of our Association and in seeking solutions to some of the vexing problems the organization faces. Their questions deserve attention.

Answers to some of these questions are already available. It is clear that there is no barrier nor any purposeful differentiation between the academic and commercial members. Definite steps have been taken to tie in the men from industry with the Association's program. In the Manufacturing Section, a man from the commercial field serves as section chairman on alternate years. More and more, the various committees are achieving a proper balance of academic and nonacademic members. Tremendous strides have been made in our Journal with the research papers being better prepared and with the feature articles and the abstracts having special industry-wide significance.

Whether or not a man from industry will serve in an important post often depends upon the time requirement. Usually an academic man operates on a more flexible program than a man from industry and has an administration which is sympathetic to staff participation in Association affairs. Many industry men decline invitations to important A.D.S.A. committees because of the time factor, and some companies frown on their men becoming too much involved in "nonbusiness" work. The heavy work load of the elected officers, especially during the period of the annual meeting, prevents many in the commercial field from accepting nominations for director or vice-president.

Our Association is blessed with many talented members from the commercial field, and their help is needed. Certainly, full opportunity should be extended to all members to serve in whatever capacity their qualifications and available time will permit. Many times leaders from the commercial field who are members of our group can and will aid in an advisory capacity even though other responsibilities will not permit them to assume a "heavy duty" job. All that is needed is an invitation.

The role of our Association is not always understood within the entire dairy industry. From statements made by nonmembers, it is apparent that our group is often considered as being "apart from" rather than "a part of" the industry. This is an unfortunate view and one which should be corrected.

There needs to be full understanding between the A.D.S.A. and the trade associations of the dairy industry. The educational and research aims of our group should be recognized as being as important to the welfare of the industry as the aims of the specialized trade organizations. Perhaps our Association has been at fault in not displaying more keen interest in industry affairs in general and in limiting attention too greatly to academic problems. Perhaps we have not told the full story of our work to those outside the Association. Perhaps this neglect by those of us in education "to sell our wares" has been the basis for the charges leveled in recent years that we are doing a poor job in training men for industry leadership.

On the other hand, the commercial trade groups may have neglected to recognize our Association for what it is and what it can do in working cooperatively with them. Our Association has not been invited to be officially represented on industry-wide committees nor to have the opportunity for an interchange of views in respect to the major problems in which all of us are interested. Industry committees have been established to study the matter of university and college teaching—but the A.D.S.A., the leading educational association in the industry, is not officially represented on

these committees. I am sure this has been due to oversight rather than any wilful intent.

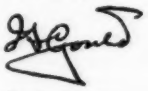
An industry leader said recently, "If a law were passed to eliminate all but one dairy association in our country, I would vote to retain A.D.S.A. because without education and research our industry would die!" Whether we agree with this leader or not, we can take pride in the importance of our Association and the contributions its members are making. However, we need to exert continued effort to obtain full understanding and cooperation with all other dairy groups if our Association is to be of still greater service in the years to come.

Two committees are now at work in connection with the Association's industry-wide activities. One is the Public Relations Committee, of which BEN ZAKARIASEN, Minneapolis, is chairman. This committee is concerned with the matter of better industry relations and Association publicity. The second committee, a new one, is to devote attention to the preparation of a manual on "Selecting, Training, and Developing Leaders for the Dairy Industry." This is planned as a companion piece to the recently published "Guide for Secondary School Recruitment Programs." H. B. HENDERSON of Georgia heads this committee, and our secretary-treasurer, H. F. JUDKINS, is contributing his experiences to this important document. Much good will come from the work of these committees.

Of tremendous importance to our Association and to all of the industry is the study made during the past year by H. B. HENDERSON of the Univ. of Georgia under the auspices of the College Relations Committee of the Milk Industry Foundation—a study to find out why our dairy enrollment in colleges and universities is low and what can be done about it. The presentation of this report at the annual M.I.F. meeting was a highlight event, and congratulations are deserved by M.I.F., its College Relations Committee headed by ROBERT E. CLEARY, and Professor Henderson.

The follow-up of this study is now in the hands of the Education Subcommittee of D.I.C. (Dairy Industry Committee) with J. H. ERB of Columbus as chairman. A definite action is being planned and it is hoped that A.D.S.A. will be called on to assist in any program which may evolve. Last spring our Association through President Moore advised some 60 leading dairy organizations of the need for approved films for a secondary school recruitment program for the dairy industry and recommended that industry-wide action be undertaken in this regard. The D.I.C. educational sub-committee is expected to develop a plan which, when activated, will result in the production of these much needed films.

Cordially,



I. A. GOULD

OUR INDUSTRY TODAY

Brief Reviews of Current Topics

Opportunities in Dairying for the Negro Farmers of North Carolina[1]

Through the application of scientific principles much progress has been made by those who have shifted from share cropping to dairy farming

W. L. KENNEDY

Dairy Husbandry Section

The Agricultural and Technical College of North Carolina, Greensboro

The Negro dairymen in North Carolina, chiefly part-time operators, are making slow but steady gains in the state's stepped-up program in milk production. This is borne out by the results of a study recently completed by the Department of Dairy Husbandry at the Agricultural and Technical College of North Carolina, the Land Grant college for Negroes in this state. Located on the campus of this college are the headquarters of the Negro personnel of the state Agricultural Extension Service and the staff of the Vocational Agricultural Division. Through these agencies the college is in contact with the farmers and the high school students of the state.

There are over 2,900 students registered in the School of Agriculture, School of Education and Science, School of Engineering, School of Nursing, Graduate School, and the Technical Institute. Of this number, 498 are enrolled in Agriculture. The curricula in the Department of Animal Industry are designed to meet the diverse interests of students by offering a choice of several options of study in which the students may specialize. Those wishing to major in animal industry may specialize in either animal husbandry, dairy husbandry, dairy manufacturing, or poultry husbandry.

The specialized options are particularly well suited to prepare the students to be operators of farms where livestock is handled, for specialized types of dairy and poultry farming, and as instructors and investigators in animal science. The 2-year curriculum offered in animal industry is designed to prepare students to be livestock farm operators, herdsmen, helpers in meat processing plants, and salesmen for feed and livestock supplies. It is intended to train personnel for formal and informal instruction; to aid improvement in production, breeding, and management.

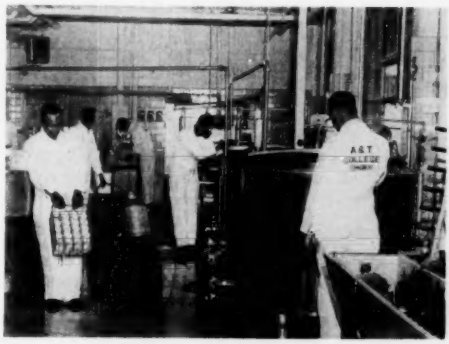


FIG. 1. The A. & T. college dairy processing plant completed in 1954. The building also houses dairy lecture rooms and laboratories. Students are trained for both dairy farming and dairy plant work.

For a number of years the college has maintained a purebred Jersey herd of 60 to 100 animals. Recently the number of Jerseys was reduced and several purebred Holsteins were added. Before the practice of artificial insemination became widespread, the college furnished a large number of purebred bulls to the farmers of the state. Heifers are furnished now when available.

Through the extension service, the college is able to contact the producing farmers. Each year in February a 3-day short course is held. During 1954 some 34 junior dairy shows were held, and nearly 1,000 animals were exhibited. In many of these shows a representative from the college acted as judge. In 1954, 2,191 farmers were using artificial breeding and 1,691

[1] This article was written at the request of the editor to show what is being done by the Land Grant colleges for Negroes to advance the cause of dairy farming in the South.

FIG. 2. Jersey heifers in A. & T. college herd.

"test tube" calves were produced. Faculty and staff members at the college assist with these programs.

Study of Farmers' Gains

A survey was conducted by the use of a questionnaire, prepared by two members of the Department of Education with assistance from the Extension Negro Dairy Specialist and the members of the Dairy Section. The information was obtained by the supervisor or a representative of the college Dairy Section, and the Negro county agent was present when the farmer was contacted. Since most of the Negro dairymen have entered business during the last 15 years, the questionnaire obtained information primarily for that period.

Conservatism, as indicated by failure to use available credit, has been the chief reason for the Negro dairyman's slow progress, but the gains which have been made are established on a firm economic basis and scientific practices. The North Carolina farmer is no longer a strictly "row-crop" producer. The trend has been toward increased livestock production, with a marked emphasis on dairying, and the Negro has, largely, followed these changing practices.

North Carolina's four million people are divided almost equally among the urban, rural nonfarm, and rural farm areas. The state has some 31.5 million acres and over 19 million are in farms, almost eight million being in crops, corn, pasture, small grain, and cotton. Together they occupy over half of the cropland but do not account for as much value as tobacco, which is produced on only 8% of the land.

Growth in Dairying

In 1930 the state had 279,522 milch cows and calves but by the 1950 census there were 391,819, an increase of 41%. There has been a marked increase in the number of dairy cattle since 1950 also. When increased dairy production was being advocated, a ready market was available because a large amount of milk was being brought from out of the state. The grade A milk being produced is now nearly meeting the local requirements; however, there is still a very large market for manufactured products. Many dairymen now selling manufactured milk could move into the grade A market when it becomes available.

The Negro dairyman has made splendid progress in the dairy industry in North Carolina during the past 20 years. As of March 1, 1955, 753 Negro farmers were engaged in dairying. Fifty-three of them are grade A milk producers. The results of the survey show the average Negro dairyman to be 48, married, and living in one of the 16 counties representing the three major farming areas of North Carolina.

Before going into the marketing of milk, 40% of the Negro dairy farmers participated in dairy cattle shows and another 5% took dairy short courses. They averaged 25 years experience as farm operators, the range being from 3 to 49 years. Only 5% of these farmers had 9 years of experience as dairy farm operators. Most of the farmers owned their farms, only 10% being tenants. Some owners rented additional land.

Use of Utilities and Agencies

All of the Negro dairy farmers had modern means of transportation. Half of them used cars and trucks. The sanitary conveniences on these farms increased significantly during the period 1945-54. Before 1945, only about 5% had such conveniences, but in 1954, 90% of the farms had modern equipment in both houses and barns.

Prior to 1945, 30% had electricity in dwellings only and 10% in both dwelling and barn. In 1954, 95% had electricity in dwellings and barns and only 5% had electricity in dwellings alone.

All these farmers had some means of communication: 40% had radios only, 30% had radios and telephone, 12% had radio and television, and 18% had radio, television, and telephone. Sixty-five per cent of them spent 15 minutes or more daily looking at or listening to farm programs.

These farmers belonged to various organizations, the Farm Bureau predominating, but practically none of them belonged to a national organization. All made use of extension services and vocational agricultural agencies.

There was a decided lack of use of credit agencies. It requires a tremendous amount of capital for farmers to adjust from small to economical sized herds. Most farmers cannot make these adjustments without some borrowed capital. Some idea of the amount of capital needed may be seen from the fact that it requires approximately $16,000 to establish a 20-cow dairy, even if the land is available. Some lack of qualification may have been the reason these farmers did not use the credit agencies available. A little over 5% used the commercial banks and the same number used the Production Credit Administration.

The Farm Operation

The average number of dairy cows on these farms was 17. The animals were predominately grade. Five per cent of the farmers kept

bulls. Most of these bulls (60%) came from private herds with the others (40%) being bull calves dropped as a result of artificial service.

Before 1945 these farmers on the average kept two to three work animals, nine hogs, less than one beef animal, and 200 chickens. Today there is a decrease in the number of work animals and poultry but no definite change in swine and beef animals.

On these farms the cost of production seemed to be in line with regular costs. The feed and labor amounted to 50.9% of the total cost. Interest, taxes, and insurance amounted to 9% of the total. The feed and labor costs reflect the influence of improved practices in breeding and management. The gross receipts averaged $6,642.90, with a range of $2,000 to $14,450; 10% amounted to $12,000 or more. The average cost of production was $4,696.83. This included feed, labor, interest, taxes, insurance, depreciation, breeding service, fertilizer, seed, and transportation. Two-thirds of the gross receipts were spent in production, leaving one-third, or $1,944.07, as "take home" pay. Through greater use of credit resources to expand operations the amount of take home pay could be increased.

The average acreage in cropland, grazing hay, and silage has shown definite increase. Before 1945 the average cropland was 49.6 acres, whereas in 1954 it was 90.5 acres. The number of acres of alfalfa averaged 5.7 in 1945 and 9.5 in 1954. For grazing there was an average of 1.4 acres of permanent pasture in 1945 and 16.7 acres in 1954. The temporary pastures increased from 13 acres to 20.1 acres during that period. The most significant change is the acreage utilized for silage. There was no provision for silage before 1949, but in 1954 there was an average of 13.8 acres of corn planted for this purpose. The improvement in methods of storing silage is also significant. Before 1949 there were no facilities for storage, but in 1954, 30% of the farmers had erected upright silos and 35% had constructed pit silos.

The methods of grazing have shown considerable change during the period under study. Two methods are control grazing and rotational grazing. In control grazing the cattle go to pasture when the forage is 6-8 in. high and are removed before the pasture is over-grazed. All livestock is kept off during the winter and at times when the ground is so soft that the pasture might be injured by tramping. In rotational grazing the pasture is divided into two or more fields, which are grazed in rotation. Only 5% of the dairymen practiced rotational grazing before 1945, 20% before 1949, and 24% in 1954. Control grazing was practiced by 10% before 1945, 20% before 1949, and 31% in 1954.

Case Histories of Two Successful Negro Dairy Farmers

JOHN D. ROBINSON, Monroe, N. C., owns a 75-acre farm that is slightly rolling and chiefly clay. He went into the dairy business to increase the farm income. He started marketing grade C milk in 1942 and grade A in 1952.

Robinson has 30 acres devoted to pasture—chiefly ladino clover and orchard grass—15 acres in corn and milo maize, 5 acres in alfalfa, 10 acres each in oats and lespedeza, and 7 acres of wheat. His rotation consists of raising row crops (cotton, corn and milo) 1 year and small grain with lespedeza the next year. He plans to increase the fertility of his soil by a rotation use of manure and commercial fertilizer. He has had a program of terracing for a number of years and has made use of legumes in the rotation.

FIG. 3. The John D. Robinson herd is maintained under better than average conditions. Not only does the farm have ample grazing, but the Robinsons have just recently completed a well planned lake to provide adequate water for the herd at all times.

He has 10 milch cows that average a little more than 5,000 lb. of milk a year. They are chiefly grade Guernseys. His best cow produced about 4,000 lb. of milk during a recent 6-month period. Mr. Robinson is making plans to cull the lower producers and to obtain better animals. He is using artificial insemination and intends to build up his herd by saving the heifer calves of the higher producing cows. He plans at the same time to increase his pasture and feed program to accommodate the additional cows.

The cows are fed according to production yield and breed. A grain mixture plus hay and silage is used, and 3 to 4 hours of grazing each day are permitted. The animals are tested annually for tuberculosis and Bangs' disease. So far, all tests have been negative. The cows are milked by machine, and the milk is cooled in cans by wet refrigeration. The milk is picked up on alternating days and is sold to a dairy in Charlotte, N. C. The income from the sale of milk was more than $3,600 last year.

Mr. Robinson plans to go into dairying exclusively. His main source of income before going into dairying was cotton. He averaged 10 acres of cotton and sold about 13 bales each year. He is now cultivating only 5 acres. Rob-

inson stated, "Dairying has enabled me to do many things I would not have been able to do otherwise. My living standard is higher as a direct result of the dairy enterprise." His advice to young dairy farmers is: "Start with fewer and better animals and adequate feed and pasture to accommodate the cows. The feed or availability of feed and pasture would be first and then the cows. When I started, it was the other way around, I didn't have enough feed for the cows I was milking."

Mr. Robinson's youngest son, now in the army, is looking forward to taking over the dairy business when his father retires.

JAMES B. BURNS, Indian Trail, N. C., owns a 60-acre farm of rolling clay soil and rents an additional 25 acres. He started his enterprise because he liked dairy animals and also wished to increase his income. He started marketing grade C milk in 1945 and changed to grade A late in 1953.

He has 20 acres in pasture, 16 acres in oats, 11 acres in corn, 2 acres in alfalfa, and 16 acres in lespedeza. The average crop production per acre has been one bale of cotton, 80 bu. of corn, and 70 bu. of oats. He plans to maintain the fertility of the soil with manure and by using legumes and commercial fertilizer. Burns has participated in the soil conservation program for a number of years. He uses terracing, has one pond, and is beginning the construction of another.

This farmer has 11 cows, chiefly grade Holsteins, that averaged 8,500 lb. of milk in 1954. In addition, he has five heifers. His best cow produced 14,900 lb. of milk in 1954. He does not plan on a large increase in the size of his herd but hopes to increase production by better management and by acquiring better animals. He is using artificial insemination in his breeding program.

Mr. Burns feeds all the silage the cows will eat. In addition, he feeds hay and grain according to production and breed. During the pasture season the animals have at least 4 hours of grazing per day. The herd is tested annually for tuberculosis and Bangs' disease. His herd is accredited.

The cows are milked by machine and the milk is cooled in cans. It is picked up on alternate days and is sold to a dairy in Charlotte, N. C. His milk checks amounted to $3,700 in 1954.

Mr. Burns' main income before entering dairying came from cotton and corn. Both are still being raised, but all of the corn and the cottonseed are used for feed. Within the next 2 or 3 years he plans to add swine or poultry to the farm enterprise and eliminate cotton entirely.

He says, "Dairying has more than doubled our income. We are enjoying a higher level of living. The cows are making it possible for me to send two girls to college." He wisely commented, "Cotton will put you in college but it will not keep you there." He had reference to the once-a-year income from this crop. He receives a milk check every 2 weeks.

FIG. 4. James B. Burns, an A grade producer, has a herd of 11 milkers. He is rapidly building his herd by buying young heifers and through careful selection of his own stock. He grows some cotton, but expects to abandon the crop within the next 3 years to practice dairying exclusively.

Mr. Burns, who is 37 years old, has a wife, five daughters, and two sons. One of his daughters, now in college, won first prize with her heifer for five consecutive years at the county level. She showed the grand champion in the 4-H Junior Dairy Cattle Show in 1947. Although the boys are too young to make definite decisions, Burns hopes that one of them will take over the farm when he retires.

These short histories of the farm enterprises of Mr. Robinson and Mr. Burns not only illustrate what the Negro dairyman is contributing to the industry of North Carolina but also show what the dairy industry can do for the Negro farmers who use modern methods of feeding, breeding, and management. As has been demonstrated many times in many sections of the country, "prosperity follows the dairy cow."

How to Control Shrinkage in Ice Cream

T. A. Nickerson and N. P. Tarassuk
Department of Dairy Industry, University of California, Davis

Shrinkage is the term generally applied to contraction in volume of packaged ice cream, a defect caused by loss of overrun air. Normally ice cream shrinks from every direction, pulling away from the sides of the container as well as from the top. This means that the phenomenon is more than a collapse of the structure and a settling of the ice cream constituents under the action of gravity.

It has been shown that the air in ice cream is in a discontinuous phase, and that the air cells are irregular bubbles surrounded by semi-solid films. Contraction of the ice cream structure should tend to compress the air and thus set up a force that would oppose shrinkage. If the air cell lamellae were fractured, the air would escape, no opposing force would be set up, and the contraction would proceed. The fundamental nature of this contractive force still remains obscure.

As experienced in the industry, the defect tends to be seasonal in nature, usually occurring in the late fall and winter. It is not uncommon for the entire production of a plant to be affected for a period of time. Then the defect disappears practically overnight, often with no indication as to the cause or remedy.

It has been shown that there are a great many factors involved in the shrinkage problem. Most of these should be classified as contributory factors rather than an actual cause, for they do not always lead to shrinkage. But if the ice cream is susceptible, then these factors intensify the defect.

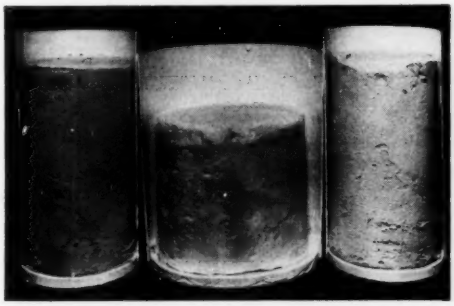


Fig. 1. Shrinkage in packaged ice cream.

Factors Definitely Contributing to Shrinkage

Ingredients. Both commercial and research workers have shown that the incidence of shrinkage is increased as the percentage of solids not fat is increased, which obviously increases the protein content of the ice cream. Present knowledge indicates that milk proteins play a fundamental role in determining the strength or weakness of the ice cream structure. The proteins may be responsible for the basic contractive force causing shrinkage, which is possibly a phenomenon similar to syneresis of gels.

Milk fat is another ingredient that promotes shrinkage, the incidence of the defect increasing as the percentage of the ingredient is increased. High fat mixes are more likely to cause trouble than are low fat mixes.

Sweetening agents do not have as marked an influence as do fat and solids not fat. With sugar, type and quantity play an important part in determining the freezing point of a mix, which relates to the firmness of the ice cream at any particular temperature. If sweetening agents are used in excess, the ice cream will not be sufficiently firm to resist shrinkage.

Ingredients such as stabilizers, emulsifiers, and egg yolk seem to play only a minor role, again contributory, and are not considered to be responsible for the spontaneous shrinkage encountered in the industry. Such ingredients are used to promote smooth texture, which, incidentally, reduces resistance to shrinkage.

Processing. The stability of the mix with respect to shrinkage also varies with pasteurization temperature. As pasteurization is increased above minimum requirements, shrinkage also is increased, reaching a maximum around 160°-170° F. Above this zone, shrinkage decreases with increased temperature. Superheating produces a cooked flavor but seems to add stability to the ice cream structure.

There is little indication that the homogenization pressures used in processing ice cream mix play any significant part in determining the susceptibility of a mix to shrinkage. Some relationship has been observed but seems insignificant.

All investigators agree on the importance of the conditions under which ice cream is frozen, hardened, and stored, for they have a marked influence on the structure of ice cream. A fine, crystalline structure or an increased fluidity within the ice cream reduces viscosity and, apparently, resistance to the contractive force causing shrinkage. Processing procedures used to produce a smooth texture—such as using continuous freezers, low drawing temperatures, and quick hardening—therefore reduce resistance to the shrinkage force. High storage temperatures reduce viscosity in like manner and may lower internal resistance markedly. In addition, it has been shown that

high storage temperatures greatly reduce the structural strength of the air cell lamellae. The cell walls can then be fractured more easily, accelerating shrinkage.

The strength of the air cell lamellae is also affected by the amount of overrun. As air is incorporated, the amount of ice cream mix per unit volume is reduced and the area of air surface stabilized by the mix is increased. As overrun is increased, particularly above 90%, the air cell lamellae are weakened, with increased liability to shrinkage.

Untreated paper containers can contribute to shrinkage. Various coatings or linings will minimize the container's contribution to the defect by restricting the movement of moisture and air.

It has been known for some time that ice cream held at normal cabinet temperatures will generally develop shrinkage if it was first stored with dry ice. There is a difference of opinion on the exact mechanism, but all agree that either the exceedingly low temperatures or the CO_2 atmosphere destabilizes the ice cream structure to the extent that severe shrinkage results.

Chemical Factors. The roles of acidity and salt balance in protein stability have been investigated as being variables possibly involved in shrinkage. The available data are inconsistent and contradictory. In some cases shrinkage can be correlated to the instability of the proteins, but control of shrinkage susceptibility by adjustment of acidity or salt balance seems uncertain at best and cannot be relied upon as a control measure.

The milk used will vary considerably in the properties that affect structural strength. It has been shown that variations in the source of the serum-solids concentrate affect the tendency of ice cream to shrink. Even the milk of individual cows has been found to vary markedly in its shrinking tendency, apparently because of variations in its proteinaceous constituents.

Experimental evidence definitely indicates that the use of rancid milk or the development of hydrolytic rancidity in the mix will cause an increase in shrinkage. This is explained by the marked lowering of the surface tension when rancidity takes place. Materials that reduce surface tension appreciably are likely to increase shrinkage substantially. Rancidity is becoming more of a problem again, and its incidence in the milk supply is on the increase.

One of the most significant results of investigations of shrinkage is the discovery that the state of the whey proteins plays a major role. Studies have shown that shrinkage is favored by the denaturation by heat or proteolysis of the albumin-globulin fraction. It appears that if the globulin fraction is present in an undenatured state, it actually stabilizes the ice cream, lessening shrinkage.

Another very important finding is that the slightest amount of proteolysis can produce spontaneous shrinkage. This means that susceptibility to shrinkage is very likely to increase as mix is stored over a period of time. The products of bacterial growth, even at low temperatures, are capable of altering the proteins sufficiently that they become exceedingly unstable, which results in severe shrinkage. Furthermore, the addition of products in which protein hydrolysis has taken place will appreciably add to ice cream shrinkage and should be avoided.

It is known that the milk proteins are a basic and major factor contributing to the strength or weakness of the ice cream structure. These proteins are in the dynamic state, changing with time. Consequently they should be used in fresh condition and should be protected from denaturation or proteolysis. From a practical point of view our other means of combating shrinkage is to govern the contributing factors so that a more rigid type of structure is produced, which will resist the contracting force.

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JOURNAL OF DAIRY SCIENCE

ABSTRACTS OF LITERATURE

W. O. Nelson, Abstract Editor

BOOK REVIEWS

742. Industrial Detergency. Edited by WM. W. NIVEN, JR. Reinhold Publishing Corporation. 1955.

"Cleaning" or "deterging" is the one most universal of all the activities of industrial enterprises. It may be the major basis for the industry (laundering, dry cleaning); an inherent part of the actual chemical or physical process by which the finished product is made (textile processing, grain milling, metal plating, foods canning); as a means of safeguarding the quality of the finished product (dairying, foods and beverages processing, restaurant), applied either to the finished product or to equipment in which the product is processed; as a means of generally upgrading the efficiency of the operation (plant maintenance, industrial housekeeping), practiced for cost reduction, safety, or esthetic advantages. This book contains several chapters of special interest to all branches of the dairy industry. Chap. 2. The Fundamentals of Detergency; Chap. 3, Detergent Materials; Chap. 7, Foods and Beverages; Chap. 8, The Dairy Industry; Chap. 11, General Industrial Cleaning. Chapter 8 is written by John R. Perry, National Dairy Products Company, Inc., who has been one of the foremost promoters of efficient cleaning and sanitizing practices for dairy plants and has designed special devices and equipment to insure cleaning efficiency. L. M. Dorsey

743. Basic Lubrication Practice. A. F. BREWER. Reinhold Publishing Corporation. 1955.

In the operation of industrial machinery there is a definite relationship between lubrication and maintenance. Each is a form of insurance to management that production will be dependable, in other words, that machinery will keep operating. In recent years a wealth of lubrication information has been developed in the research laboratories of the petroleum industry and those of machinery manufacturers, much of it of highly technical character. The object of this book is to translate such information for practical application by the plant lubrication engineer or maintenance superintendent. Their primary concern involves (1) the operating conditions, (2) the basic mechanisms, and (3) the means provided for lubrication. In 24 chapters this information is provided in easily understood language amply illustrated with drawings, diagrams, photographic reproductions, and tables. The various types of machinery requiring efficient lubrication practices, many of them in use in milk products processing and manufacture are adequately treated. L. M. Dorsey

BUTTER

744. Consumer purchases of butter and oleomargarine. J. D. SHAFFER and G. G. QUACKENBUSH, Mich. Agr. Expt. Sta., East Lansing. Tech. Bull. 248. 1955.

During the years 1942 to 1952, per capita consumption of butter declined 44.6%, while oleomargarine consumption increased 185%. Analysis of two years of weekly data for Lansing indicated that butter consumption was declining about 5% annually and oleomargarine was increasing the same amount. In surveys taken during the summers of 1949 and 1954, 80% of those not using butter in 1949 said it was because the product was too expensive. In 1954, this reason was given by only 59% of the nonbutter consumers. The most important reason given for not using oleomargarine was a preference for the taste of butter. In 1949, 77% reported using butter on the table, compared to 67% in 1954. Based upon data for the entire year of 1952, 10% of those interviewed used only butter, 13% only oleomargarine, and 77% purchased both. Large consumers of butter used less oleomargarine, but approximately the same amount of lard and vegetable shortening as the ave. Large oleomargarine users appear to use slightly less vegetable shortening and lard. During the period July 1, 1951 through June 30, 1953, the annual per capita expenditure for oleomargarine and butter was $9.52, of which $7.09 went for butter. R. W. Hunt

745. Effect of variations in the manufacturing process on body and texture of butter with special emphasis on spreadability. L. C. THOMSEN, Dept. of Dairy and Food Ind., Univ. of Wis., Madison. Milk Prod. J., **46**, 10: 21. 1955.

The author stresses the need for butter manufacturers to place more emphasis on its spreadability characteristics. After a brief discussion of the term "spreadability," the author lists numerous devices that have been used for measuring the spreadability of butter.

The spreadability apparatus, constructed and used at the Univ. of Wis., consists of a constant speed motor, mounted so that it pulls a carriage over a box containing the butter sample. The carriage holds a specially constructed knife which in its movement attempts to duplicate the action required to spread butter on bread. The resistance offered to the knife by the butter is registered on a semicircular dial which is part of a moving torque meter. The lower the pull or resistance, the better is the spreadability of the butter sample. Butter samples should be tempered for a period of 48 hours at a constant temperature (55.5° F.).

Results of this measuring device have been checked against more than 400 pairs of butter samples submitted to consumers who rated samples only according to their ease of spreading. Statistical analysis of the results indicated a highly significant correlation between the machine and the consumers. In terms of sensitivity the machine was from 10 to 20 times more accurate than the average consumer.

The major problems involved in the improvement of spreadability of butter are briefly discussed. J. J. Janzen

746. Spreadability of butter. S. T. COULTER, Univ. of Minn., St. Paul. Milk Prod. J., **46**, 10: 17. 1955.

The author stresses the importance of manufacturing a butter with reasonable spreadability even at refrigerator temperatures. The manufacture of a butter which is smooth and waxy in body and reasonably spreadable can be made throughout the season by proper manipulation of manufacturing procedures.

Such manipulations include adjustment of the rate and extent of cooling of the cream, adjustment of the rate at which the butter is chilled, and avoiding unnecessary and excessive fluctuation in the temperature of the butter.

The need for an adequate objective measurement of the spreadability of butter, and increased interest, on the part of management, in the body characteristics of the butter produced, are stressed. J. J. Janzen

747. Sliced butter for consumers. ANON. Milk Prod. J., **46**, 10: 14. 1955.

Butter patties, formerly available only to hotel, restaurant, and commercial channels, are now available to consumers.

Hotel Bar Foods, Inc., of New York City, began marketing this product in March, 1955. Each ¼ lb. of butter is sliced into 16 equal portions. They come apart with a gentle twist. No additional charge has been made for this sliced feature.

The equipment for slicing the ¼ lb. prints fits standard forming and wrapping machinery. The slicer fits between the extruder-former and wrapping sections of a print-forming and wrapping machine. The slicing machine has three stages which: (1) receives butter from the extruder; (2) holds it under the guillotine while it is being sliced; and (3) transfers it to the wrapping unit. The machine can process 8,800 ¼-lb. packages an hour. Similar units have been installed at two other food companies. J. J. Janzen

748. Spotted color in butter. R. M. DOLBY. New Zealand J. of Sci. and Technol., A, **36**, 6: 527. 1955.

The defect is characterized by the presence of numerous dark-yellow spots seldom exceeding 2 or 3 mm. in diameter; the butter between the spots is usually uniform in color. It is caused by the presence of undissolved salt crystals and can appear in well worked butter.

The quantity of water in the butter available for dissolving the salt was found to be the most important factor. Water enclosed as fine droplets within the granules ("internal" water) is not available. Some two-thirds of the usual total of 15% water is "internal" water. Factors that increase the amount of "internal" water and hence increase the tendency toward spotted color include Vacreator treatment of cream, dilution of cream, slow cooling of cream, high churning temperature, and churning to large granules. Salt milled to 100-200 mesh could be used safely under conditions where salt of normal particle size caused the defect.
W. K. Jordan

CHEESE

749. Improving the flavor of cottage cheese by the addition of citric acid to the milk. J. A. NELSON and J. L. BRENCE, Mont. Agr. Expt. Sta., Bozeman. Bull. 488. 1953.

Of a total of 116 vats of cottage cheese, 80 were made by "short time" method and 36 by a "long time" method. In some trials, citric acid was added to the culture, and in others it was added to the milk before inoculation. Volatile acidity was determined by steam distillation, and flavor of the cheese and cultures was determined organoleptically. An addition of 0.008 to 0.005% citric acid to the cheese milk before inoculation increased the volatile acidity sufficiently to result in an improvement of flavor in the cheese. The volatile acidity of "long time" cheese was generally higher and, consequently, the cheese was considered to have a greater intensity of flavor than "short time" cheese. A volatile acidity of 10 ml. of 0.1 NaOH per liter of distillate had to be reached before there was a noticeable improvement in flavor.
R. W. Hunt

750. Flexible wax compared with paraffin as coating for cheese. F. COFFEY, Kraft Foods Co., Glenview, Ill., and C. SWETT, National Wax Co., Chicago, Ill. Milk Prod. J., **46**, 9: 14. 1955.

An effective wax coating should allow the proper curing of the cheese, prevent the cheese

from drying out, withstand the shock of handling during shipping, and protect the surface from mold and cheese mite infestation. A series of tests was conducted to determine whether flexible wax or paraffin wax fulfilled these requirements.

Best results were obtained by using two dips of flexible wax on properly dried cheese surface at 250° F. A clean dry surface was essential. Cheese contaminated by milkstone or slime from shelves and then held at high humidity and temperature had a tendency to become slippery or "rind rot" after coating with flexible wax. This condition was less pronounced with paraffin wax probably because some drying occurred through the paraffin wax. The mold growth on properly dried cheese surfaces coated with flexible wax was much lower than on paraffined cheese. Two dips afforded better protection and greatly reduced moisture loss in the cheese. Excessive waxing temperature (290° F.) may be detrimental. The tendency to crack and break away from the cheese was decidedly less in flexible wax coating than in paraffined cheese. This property of flexible wax provided more protection for the product during transit and also reduced the probability of mite infestation.

J. J. Janzen

751. Automatic cheesemaker cuts labor and cost. ANON. Milk Prod. J. **46**, 9: 13. 1952.

Automatic cheesemakers are used extensively in Germany. The first of its kind in the U. S. has recently been installed in a factory near Mayville, Wisconsin.

The machine consists in part of a vat that will hold 11,000 lb. of milk. Labor is cut in half compared to old methods. As a result, cost of making cheese was reduced about 20% at this factory. A 1,000 lb. of curds can be emptied out of the machine vat in 11 min. with the aid of a partial vacuum feature.

At present about 20% of this plant's production is made with the "Kaesefertiger," as the machine is called. Port Salut, Gouda, Colored Brick, May Cheese, Venetian Cheese, and Leyden have been produced by use of this equipment.

J. J. Janzen

752. Cheese you can freeze. H. A. MORRIS and W. B. COMBS, Univ. of Minn., St. Paul. Milk Products J., **46**, 10: 12. 1955.

The following cheese can be frozen and stored for at least six months: Cheddar, Brick, Port du Salut, Swiss, Provoloni, Mozzarella, Liederkranz, Camembert, Parmesan, and Romano. Cream cheese becomes watery and mealy after freezing, thus cannot be frozen satisfactorily.

To prepare cheese for freezing, cut all pieces of cheese larger than 1 lb. into pound or ½-lb. pieces. Cut cheese should be tightly wrapped in aluminum foil. Cheese that is small in size may be left in its original package. Thawing of the frozen cheese is important and should be done in the refrigerator.

A series of pictures is presented showing the texture of a variety of frozen cheese.

J. J. Janzen

753. "Nuworld" cheese now on market. ANON. Milk Prod. J., **46**, 9: 48. 1955.

Called "Nuworld," the semi-soft cheese is an invention of the Univ. of Wis. and a development of the Univ. of Minn.

The cheese is distributed throughout Wis. and is available in attractive 4-oz. wedge-shaped resealable packages with heavy aluminum foil wrapping imprinted in green and black.

The flavor of the cheese is described as being on the order of Camembert, Gruyere, Aged Swiss, Roquefort, or Blue Cheese, but not quite as tangy. Consumer surveys reveal that this natural, semi-soft cheese is ideal as a snack, salad, or dessert cheese.

J. J. Janzen

CONDENSED AND DRIED MILKS; BY-PRODUCTS

754. Studies on high temperature sterilization of evaporated milk with emphasis on stability aspects. C. O. BALL, Dept. Food Technol., Rutgers Univ., New Brunswick, New Jersey. Food Research, **20**, 4: 351. 1955.

A detailed study of high temperature short time sterilization of evaporated milk by the agitated can method, accomplished with fast heating, resulted in a product with improved flavor but with shorter shelf life than the conventional product because of instability of texture and flavor. Acidifying milk and blending it with alkalized or normal milk improved texture stability by increasing viscosity (short of coagulation). In such cases, the higher the intensity of agitation during sterilization the higher the viscosity in the finished product. A higher intensity of heat was required in this method to produce stability against cream separation and gelation than to give sterilization, whereas in conventionally sterilized milk the three objectives are accomplished at about the same severity of heating. Controlled distribution of high-short sterilized evaporated milk seems necessary to insure that the product is used within its period of flavor and texture stability.

F. J. Doan

DAIRY CHEMISTRY

755. Atomic energy in agriculture. K. L. ENGLUND, Hanford Operations Office, A. E. C., Richland, Washington. J. Agr. and Food Chem., **3**: 826. 1955.

The article is an interpretative review of the role of atomic energy in agriculture.

S. Patton

756. The deterioration of milking rubbers. IV. Fat in milk liners. J. H. COOPER, Avon India Rubber Co. Ltd. Melksham, Wilt. J. Dairy Research, **22**, 2: 138. 1955.

Rubber milking machine liners were boiled in acetone and then distributed to three farms

for use over a 5-7 week period, after which time they were cut into segments and extracted again with acetone. The mouth piece section absorbed mainly fat which had characteristic of udder-skin fat. The fat in the barrel was a mixture of skin fat and butterfat. Approximately 50% of the fat found in the rubber liners was from the skin. J. D. Donker

757. The deterioration of milking rubbers. V. The effect of rubber composition. P. M. CLARKE and N. J. BERRIDGE, N.I.R.D., Univ. of Reading. J. Dairy Research, **22**, 2: 144. 1955.

Several natural rubber formulations were compared with blends of natural rubber and Perbunan, butadienacrylonitrile rubber, as sources of materials to make milking liners. Field use observations included amount of fat absorbed, increases in length and diameter of liners, degree of ozone cracking and number of flexings before becoming perforated. The addition of Perbunan greatly increased the resistance to fat contrasted to minor differences brought about by use of different accelerators and fillers in natural rubber mixes. Carbon black appeared to be superior to chalk as a filler in these trials. J. D. Donker

DAIRY ENGINEERING

758. Keeping your fill on the level. ANON. Milk Prod. J., **46**, 9: 12. 1955.

A new electronic unit, designed to check underfills, is being used in evaporated milk operations. This unit has a minimum of moving parts and takes up a minimum of floor space. The principle of the unit's function is simple. A narrow X-ray beam, whose height is adjusted to the desired fill level, crosses the conveyer at a right angle. When fill is incorrect, the X-ray beam is so altered as to register on a detector. The amplified signal from this detector triggers the rejecting device. The level checker can be adjusted to check either overfill, underfill, or both.

The X-ray unit measures the fill without mechanical contact of the containers under inspection. The narrow X-ray beam responds to a level variation of 1/32 inch and has an inspection speed as high as 900 containers a minute. Rejection can be made by means of an air blast—or rejection devices of other types if they are better suited.

The level checker has only one moving part, the shutter, that operates the X-ray beam. No radiation problem exists because the beam is quite small and all shielding required is included in the unit's design. J. J. Janzen

759. Automatic doors save time and refrigeration. ANON. Milk Prod. J., **46**, 9: 16. 1955.

The use of automatically controlled sliding doors for cold storage rooms is briefly discussed. These doors are especially suitable in fork truck operations. Operating costs are nominal and savings in refrigeration can be considerable.

J. J. Janzen

DAIRY PLANT MANAGEMENT AND ECONOMICS

760. Some pricing and regulatory effects of the Federal Order on the Tulsa milkshed. L. V. BLAKLEY and D. BREWER, Okla. Agr. Expt. Sta., Stillwater. Bull. B-451. 1955.

This study of the size and type of adjustments in milk production associated with the pricing and regulatory effects of the Federal Order was made in the Tulsa milkshed by personal interviews with Grade A milk producers and covered the years 1949 through 1952. The adjustments to the pricing and regulatory effects of the Order are as follows: Before the Order, the discount on milk testing below 4% was 10¢ for each point; under the order, the discount was 7.5¢. As a result, dairy farmers began using lower testing herds. With the decrease in butterfat emphasis, milk production increased. Consequently, the pricing procedure was flexible enough to allow for adjustments of milk tests to market demands. For the test period (1949-'52), the adjustment was a change of 1% in the milk test level for each 4.4% change in the butterfat price differential. Changes in milk prices relative to beef prices and changes in weather appeared to be the most important factors influencing milk production. Milk production increased and decreased at about the same rate as the relative price change, since the Order governed only milk prices. R. W. Hunt

761. How Chicago's PMA finances farm bulk tanks. ANON. Milk Prod. J., **46**, 10: 18. 1955.

Under the Chicago PMA plan, when an entire plant wishes to switch to bulk, the milk dealer agrees to pay at least 15¢ per cwt. premium for bulk tank milk, until this premium of 15¢ or more equals ¾ of the cost of the bulk tank plus 16%, estimated interest and finance charges.

The cost of the bulk tank, under this plan, includes the actual cost of the tank less any allowed discount for trade-ins, the setting up of the tank and compressor in the milk house and its placing in a satisfactory operating condition, the electrical wiring inside the milkhouse necessary for operation of the bulk tank, and calibration of the tank.

The estimated interest and finance charges of 16% include interest at not more than 6% per annum on the unpaid balance for about 5 years. The amount to be financed includes the actual price of the tank less discount and trade-in credits, installation charges, interest and finance charges, and payment of $20 to repossession fund.

The milk dealer agrees, by written assignment, to deduct at least 20¢ per cwt. (at least 15¢ to be paid by the milk dealer and an additional 5¢ by the producer) from the producer's milk check every month and remit the amount to the PMA until the assignment expires.

The producer, under this plan, agrees to

purchase and pay for his bulk tank in monthly payments at the rate of 20¢ or more per cwt. (the actual bulk premium plus 5¢ per cwt.) provided these payments will be at least 1½% of the total loan or $20, whichever amount is the largest.

The producer also agrees to pay $20 into a repossession fund to be held by the PMA for the purpose of reimbursing a tank dealer for his loss in the event that a bulk tank is repossessed due to default in payment by a producer.

The PMA agrees to remit the producer's monthly deductions to the owner of the indebtedness and to keep a record of the producer's monthly payments. The PMA also agrees to reimburse the bulk tank dealer out of the repossession fund with a maximum payment of $200 for his losses incurred in the event that a tank is repossessed within 2 years from the date of installation.

The bulk tank dealer guarantees to provide a tank which the manufacturer pledges will meet the prescribed standards set by the Pure Milk and Associated Milk Dealers Joint Technical Committee. These include compliance with 3A Sanitary Standards as of the date the tank is installed, compliance with regulations of the health authorities concerned, and a 10-year warranty on the bulk tank plus a 5-year warranty on all compressors.

Financing has been arranged through local banks and is meeting with acceptance from all quarters. J. J. Janzen

762. Three processors team up and win multi-savings. R. A. Latimer. Food Eng., **27**, 9: 92. 1955.

An ice cream manufacturer, a mix producer, and a wholesale milk dealer combined operations in a single new plant. Marked savings resulted from employment of a single boiler and a common refrigeration system, interchange of personnel from one type of production to another, combining of sales and office work, and elimination of duplicated deliveries. The carefully engineered and modernly equipped plant contributes to highly efficient operation.
T. J. Claydon

763. Materials handling equipment. C. O. Davis. Milk Plant Monthly, **44**, 9: 28. 1955.

A nation wide survey concerned with the use of lift trucks, conveyors, and palletization in milk plants showed that there is interest throughout the industry in more efficient handling of materials, particularly regarding loading and unloading of delivery trucks. Except for the use of conveyors, the industry has only begun to convert its hand-labor to machine-labor. C. J. Babcock

764. New British plant uses automation. W. Sekules, British Correspondent, Universal Trade Press Syndicate. Milk Plant Monthly, **44**, 9: 25. 1955.

A description of the Express Dairy Company's "Milk Center," in Morden just outside of London, where bottles arriving from distributing dairies pass thruogh the process of washing, filling, capping, and crating without being touched by human hands. It is one of the largest dairy organizations in the world and owns 7 bottling dairies, 125 retail distributing depots, more than 300 shops and 50 restaurants and cafeterias. It can handle up to 1,100,000 bottles of milk per day, holding 120,000 gal. of milk. C. J. Babcock

765. Plant expansion without enlargement. Staff Editors. Milk Plant Monthly, **44**, 9: 21. 1955.

The Twin Pines Farm Dairy of Detroit, Michigan's largest, switched from cylindrical to rectangular tanks to make better use of existing floor area and increase storage capacity from 18,000 gal. to 40,000 gal. The rectangulars are about 1 ft. narrower and 2 ft. shorter than the cylindrical tanks of the same capacity. The rectangular tanks can be placed side-by-side and walled-in, thus eliminating the additional space for cylindrical units. The rectangular tanks make possible a 40% savings in floor area and a 2 ft. reduction in aisle space, while increasing capacity as much as 60% for given wall area. C. J. Babcock

FEEDS AND FEEDING

766. Year-round grazing on a combination of native and improved pasture. D. W. Jones, E. M. Hodges, and W. G. Kirk, Fla. Agr. Expt. Sta., Gainesville. Bull. 554. 1954.

A successful management system involves the supplementation of native pastures with improved pastures. A supplementation program of this type reduces the necessary pasture acreage per cow and provides higher quality feed. Additional feed supplies are realized, especially during winter feeding periods, because of a deferred grazing schedule which is possible under this system. An advantage of the supplemental pasture system is that pasture acreage can be adjusted to changes in herd size.
R. W. Hunt

767. Wood molasses as a feed for milking cows. E. A. Keyes, Mont. Agr. Expt. Sta., Bozeman. Cir. 202. 1953.

Crude molasses can be made from wood wastes by hydrolyzing with dilute sulfuric acid, neutralizing with calcium oxide, filtering out most of the calcium sulfate, and then evaporating excess water to obtain a product of 45-55% sugar. The results of this experiment indicate that wood molasses can be used in feeding cows without affecting milk production. R. W. Hunt

768. A study of winter disorders in cows and ewes fed low-quality roughage. C. K. Whitehair and W. D. Gallup, Okla. Agr. Expt. Sta., Stillwater. Tech. Bull. T-53. 1955.

Protein deficiency was observed when cows and ewes were fed poor quality roughage. Several diseases contracted by the experimental animals are described. R. W. Hunt

769. Labor used in crop production in Tennessee, 1953. Part IV. Hay, pasture, and cover crops. W. P. RANNEY. Tenn. Agr. Expt. Sta., Knoxville. Cir. 5. 1955.

Most of the variations in labor used per acre were accounted for by the yields of hay, level of mechanization in harvesting, kind of crops, and time of establishment. Higher yields per acre require more labor. When loading and hauling loose, an increased yield of 1 T/acre resulted in approximately 2.6 more man hours; bailing added about one extra hr. The group of farmers using horses averaged 40% more labor than those using tractors. The total labor required for preparing the seed bed and harvesting was highest for alfalfa and lowest for lespedeza clover, and timothy seeded in small grain. However, when computed on a "per ton of hay" basis, the hours of labor were lowest for alfalfa and highest for soybeans.

R. W. Hunt

770. Seasonal distribution and production of forage and milk from orchard grass–ladino and blue grass pastures. V. G. SPRAGUE et al., Pa. Agr. Expt. Sta., State College. Bull. 592. 1954.

Productivity under 5 different management treatments of orchard grass–ladino clover pastures was studied for 5 years in comparison with a rotationally grazed, well managed Ky. bluegrass–white clover pasture. The 5 treatments were: (1) early spring grazing, (2) deferred spring grazing, (3) early spring grazing followed by removal of aftermath for hay or silage and later by rotational grazing, (4) removal of first crop for silage, followed by rotational grazing, and (5) continuous grazing throughout the season.

Greatest milk production came from the orchard grass–ladino clover paddocks on which "deferred" grazing was followed by rotational grazing. "Continuous" grazing was second highest. Ky. bluegrass paddocks produced about ⅔ as much as the better orchard grass plots. About half the production from the "deferred" paddocks came in May. "Early spring" grazing followed by rotational grazing was most conducive to maintaining the stand of ladino clover. "Continuous" grazing tended to promote survival of the smaller types of clover and also aggravated "spot" grazing.

R. W. Hunt

GENETICS AND BREEDING

771. A study of variation in twin cattle. IV. Emergence of permanent incisor teeth. G. WIENER and H. P. DONALD, Agr. Research Council, Edinburgh. J. Dairy Research, **22**, 2: 127. 1955.

Data are presented on variation in age at eruption of permanent incisor teeth in one-egg (MZ) and two-egg (DZ) twins and in pairs of half sisters (HZ). The 1st pair of incisors erupted when the animals were, on average, 100 weeks old and the other three pairs came at, roughly, 26 week intervals thereafter. Variation in age at eruption increased from 1st to 4th incisors, but the coefficient of variation remained constant at about 8%. The mean interval between eruption and complete emergence was about 5 weeks for the first three pairs of teeth and nearly 10 weeks for the 4th pair.

Variation in age at eruption within MZ pairs was no greater than between left and right sides of the same animal. DZ displayed greater within-pair variances than MZ twins, and HZ pairs greater than DZ.

Correlations of age at eruption of teeth with body weight and with gain in weight were negative but non-significant. Age at eruption of 1st and 3rd teeth was positively correlated with age at 1st and 2nd calving, but eruption of 2nd and 4th teeth was not.

For 2nd, 3rd, and 4th incisors, the intra-pair variance of the HZ group was in excess of that expected. This can be interpreted to mean that the estimates of environmental and genetic variation derivable from MZ and DZ pairs are not adequate to account for all the variation within HZ pairs. J. D. Donker

HERD MANAGEMENT

772. Relative merits of four methods of harvesting and preserving alfalfa forage for dairy feed. J. B. SHEPHERD et al., U.S.D.A. Washington, D. C. Cir. 963. 1955.

The Beltsville experiments were conducted over a 5-year period to determine the relative merits of harvesting forage as field-cured hay, barn-dried hay, wilted silage, and dehydrated hay. Results show that in climates where rain occurs frequently during the harvest period, it will be to the farmer's advantage to harvest his hay crop as silage or barn-dried hay. In these experiments, more nutrients were preserved by making silage or barn-drying the hay crop than field-curing, even when the weather was favorable. The investment of a field drier will be between $8,000 and $10,000. Stationary dehydrators will cost between $50,000 and $150,000. R. W. Hunt

773. Dairy calf losses in the Kentucky Agricultural Experiment Station herd. C. A. LASSITER and D. M. SEATH, Ky. Agr. Expt. Sta., Lexington. Bull. 622. 1955.

Herd records were used for this study and covered the period from Aug. 12, 1928 to Dec. 31, 1952. Including abortions, 1,067 births were reviewed. Calf losses averaged 14.43%, with the principal causes being abortions and calves born dead. Scours and pneumonia were the main causes of death of the live-born calves.

Of the calves born alive, 52.6% died before they were 28 days old and 84.2% before they were 56 days old. Calf losses were highest in January. R. W. Hunt

ICE CREAM

774. Factors affecting purchases of ice cream for home use. G. G. QUACKENBUSH and J. D. SHAFFER, Mich. Agr. Expt. Sta., East Lansing. Tech. Bull. 249. 1955.

A total of 240 families was surveyed to determine demands and purchase patterns of ice cream bought for home use. Extensive use was made of records of 128 families, each of whom reported 50 or more weeks in 1952. Ice cream for consumption in the home is becoming an increasing proportion of total consumption, with a present rate of purchase of about 58%. Temperature changes of 5° were associated with about 5% change in quantity purchased in the same direction. A 10% change in current income apparently reduced purchases about 2% or vice versa. A 10% change in price affected purchases by about 9% in the opposite direction.

Using purchases for 1952, difference in per capita consumption among the 128 families could not be adequately explained by difference in income, size of family, or age of homemaker. Families with high expenditures for ice cream purchased the product 66% of the weeks, while those with low expenditures bought it only 12% of the weeks. High expenditures for ice cream did not affect expenditures for other dairy products. Over the 104 weeks from mid-1951 to mid-1953, the percentage of families purchasing ice cream varied more with temperature changes than did quantity of purchase.
R. W. Hunt

775. Cabell's presents case for mellorine. ANON. Ice Cream Field, **66**, 3: 52. 1955.

It is claimed that promoting a mellorine-type product called 'd'Zert' has not interfered with ice cream sales. W. C. Cole

776. Laws on "other" products. ANON. Ice Cream Field, **66**, 3: 34. 1955.

Details of survey by Ice Cream Field gives the status of ice milk, mellorine, and diabetic ice cream for each of the 48 states. Tabulations show that 41 states allow ice milk; 11 states permit mellorine type products; and 33 states authorize the manufacture and sale of diabetic ice cream.

777. Dairy reports on ice milk. ANON. Ice Cream Field, **66**, 3: 42. 1955.

It is reported that the sale of Golden State's ice milk accounts for ¼ of the dairy's total package sales and together with ½-gal. ice cream accounts for more than ½ of their package sales. These two items represent almost ⅓ of the total frozen dairy products sales for the dairy. W. C. Cole

MILK AND CREAM

778. Can bulk conversion improve quality? H. V. ATHERTON, A. BRADFIELD, and P. E. GOTTHELF, Univ. of Vermont, Burlington. Milk Plant Monthly, **44**, 9: 15. 1955.

Approximately 175 flavor comparisons made between individual deliveries of 18 patrons under can cooling conditions of 1952 and the deliveries of these 18 patrons under bulk cooling systems for the same month of 1954 showed that feed flavor predominated in both years. A decline in the incidence of unclean, rancid, and high acid flavors was noted between 1952 and 1954, with an increase in flat and in weedy flavors during the same period. However, despite a slight improvement in milk flavor for the samples as a whole, about ⅓ of the deliveries sampled in 1954 scored lower in flavor evaluation than the comparable deliveries in 1952, and ⅓ of the farms are delivering milk with higher average bacteria counts on a bulk tank cooling system than were obtained from the same farms previous to bulk tank installation. C. J. Babcock

779. Prevention of sunlight flavors. H. J. VELANDER and S. PATTON, Pa. State Univ., State College. Milk Plant Monthly, **44**, 9: 18. 1955.

The following recommendations are made to prevent sunlight flavors: (1) Avoid bottled milk as an outlet for milk of poor bacteriological quality. Since as little as four milligrams of free methionine per quart greatly increase the susceptibility of milk to sunlight flavor, it is clear that conditions which might promote protein hydrolysis should be avoided. (2) Do not use tryptic enzyme-type antioxidants in milks which may be exposed to direct sunlight. It has been shown recently that such enzymes produce sufficient protein hydrolysis to enhance susceptibility of milk to sunlight flavor formation, (3) Where practicable use amber or ruby colored glass bottles rather than conventional uncolored bottles. It is well established that these colored bottles afford substantial protection to both the flavor and the vitamins of milk exposed to sunlight. The usefulness of paper containers for this purpose depends mainly on their thickness, (4) Where permissible addition of a suitable antioxidant is recommended. Such measures are helpful in preventing that component of sunlight flavor resulting from milk fat oxidation, and (5) When possible use lightproof boxes at the customer's doorstep. This measure, although expensive, is an ideal solution to the problem.
C. J. Babcock

NUTRITIVE VALUE OF DAIRY PRODUCTS

780. Milk protein invaluable source of "body building blocks." R. G. HANSEN, Dept. Dairy Sci., Univ. of Ill., Urbana. Milk Prod. J., **46**, 10: 24. 1955.

Nutrition experiments reveal that the healthy body needs a daily supply of at least 8 essential amino acids to help growth and maintain normal body functions during adult life.

The recommended daily intake of the essential amino acids is: tryptophan, 0.5; methionine, 2.2; threonine, 1.0; phenylalamine, 2.2; lysine, 1.6; valine, 1.6; isoleucine, 1.4; and leucine, 2.2 g.

Factors determining how effective a protein will be in helping the body reach and maintain protein nitrogen balance or equilibrium are: (1) the completeness of a protein with respect to its content of the essential amino acids. (2) the supplemental value of one protein with another. (3) the importance of a simultaneous intake of protein foods with other components of a good diet.

Known nutrition facts indicate that milk, dry milk, and cheese contribute important amounts of all the essential amino acids. The nonfat fraction of milk and milk products contains an abundance of several of the eight essential amino acids necessary for growth and body maintenance during adult life. One quart of milk daily, or its equivalent in dairy foods, will provide all the essential amino acids required by the average man. Foods of animal origin, like fluid milk, evaporated milk, dry milk, and cheese, are richer in the variety and total amount of essential amino acids than are foods of plant origin. Milk is especially important as a protein food to supplement foods low in one or more of the essential amino acids. Milk contains an abundance of lysine and supplements the deficiency of this amino acid in cereals and breads. Proteins present in dairy foods have a high nutritional value because of their excellent balance of amino acids.

J. J. Janzen

781. What's doing in research. ANON. Milk Prod. J., **46**, 9: 30. 1955.

A total of 33 nutrition research projects are being supported with funds from the dairy industry. The Dairywide Coordinating Committee on Nutrition Research presents a list of these projects. J. J. Janzen

PHYSIOLOGY AND ENDOCRINOLOGY

782. Reviews of the progress of dairy science. Section A. Physiology of dairy cattle. The biochemistry and microbiology of the rumen. D. C. EDWARDS, Hannah Dairy Research Inst., Kirkhill, Ayr, Scotland. J. Dairy Research, **22**, 2: 232. 1955.

This review contains 171 references taken mainly since 1952. There are sections on ruminant saliva, rumen gases, rumen bacteria, rumen protozoa, cellulose digestion, other carbohydrates, volatile fatty acids, lactic and succinic acids, non-protein nitrogen and vitamins.

J. D. Donker

783. Gastric urease. H. L. KORNBERG and R. E. DAVIES, Univ. of Sheffield, England. Physiol. Rev., **35**, 1: 169. 1955.

The presence of urease has been demonstrated in the gastric mucosa of dogs, men, cats, mice, sheep, bullocks, goats, and frogs and possibly other species. However, experiments have shown this urease to be of bacterial origin, playing no role in gastric physiology.

E. G. Moody

784. Symposium on the regulation of the performance of the heart. L. N. KATZ, editor, Michael Reese Hospital, Chicago. Physiol. Rev., **35** 1: 90. 1955.

The symposium consisted of nine papers relating to the regulation of heart performance. The papers pointed up the sharp differences of opinion regarding the manner in which the performance of the heart is regulated under various conditions. The reader will have to arrive at his own stand until future events more clearly define the actual importance of the several mechanisms responsible for the regulation of the performance of the heart. The editor reported that in the intact animal the factors affecting the work and oxygen consumption of the heart are:

1. End-diastolic volume which in turn is a function of filling pressure, cardiac tone, time available for filling, and systotic residue.
2. The manner in which contraction is accomplished, viz. whether it approaches an isovolumic or an isobaric contraction.
3. Neurogenic, humoral, and other extrinsic factors.
4. Heart rate changes. E. G. Moody

785. Recent developments in our knowledge of bile salts. G. A. D. HASELWOOD, Guy's Hospital Med. School, London, England. Physiol. Rev., **35**, 1: 178-196. 1955.

Author summarized discoveries and speculation which recently have led to modifications in views concerning the origin, function, and metabolism of the bile salts. E. G. Moody

SANITATION AND CLEANSING

786. Spray system cleaning. ANON. Milk Plant Monthly, **44**, 9: 31. 1955.

One of the significant differences between the spray method and the conventional circulation method of cleaning is that heat is applied directly to the cleaning solution by means of system injectors and not through operation of the processing equipment itself. Another departure is that smaller volumes of cleaning solution are required, allowing for greater concentration and the use of less detergent. A typical alternate procedure for cleaning by the spray system is given. The significant advantages are savings in labor, water, steam, detergents, and more satisfactory results. C. J. Babcock

787. **Physiological basis for insect resistance to insecticides.** R. L. METCALF, Univ. of Calif., Riverside. Physiol. Rev., **35**, 1: 197. 1955.

Reviewed were both field and laboratory results obtained from studying the development, inheritance stability cross resistance, and biochemistry of resistance in various species. Some practical control measures for resistant insects were discussed. The author concluded with the optimistic note that notable resistance has occurred in less than 0.1% of the more than 5,000 insect species of economic importance. This was the basis of the hope that resistance will continue to be the exception rather than the rule. E. G. Moody

788. **Cleaning and sanitizing dairy equipment.** W. C. COLE, Arden Farms Co., Los Angeles, Calif. Milk Plant Monthly, **44**, 8: 16. 1955.

The development of today's basic cleaners, properties of available chemicals, and uses of various cleaners and compounds are discussed. Excellent cleaning materials formulated to effectively solve most dairy cleaning and sanitizing problems are now available. Adherence to good practices and procedures is essential if the materials are to function as they should. In each plant, the cleaning problem should be evaluated, and cleaning and sanitizing materials best suited for the respective jobs be secured. Proper procedures should be established, and those responsible for cleaning and sanitizing should be properly instructed in order to best fulfill their responsibility. C. J. Babcock

789. **3-A standards.** C. A. ABELE, Diversey Corp., Chicago, Ill. Milk Plant Monthly, **44**, 8: 21. 1955.

The 3-A standards are discussed. Since the spring of 1946, standards have been formulated and published for 14 types of equipment and for two procedures. Four sanitary standards have been revised or amended. Sanitary standards for eight or more additional types of dairy equipment are in process of formulation by task committees. C. J. Babcock

790. **Fly and insect control. III. Protecting milk in the milk house and processing plant.** ANON. Milk Prod. J., **46**, 8: 16. 1955.

This is the third and final article of the series dealing with fly and insect control. The importance of keeping insects out of packaged foods is stressed.

Piperonyl butoxide and pyrethrins have been adjudged by the government regulatory agency concerned with foods to be the safest of all toxicants used for insecticidal purposes. This combination may be used freely in the milk house and around dairy products without fear of contamination, or of any adverse effect upon the flavor of nearby foods. Other chemicals are briefly discussed.

The importance of sanitation as the first step in the control of insects is stressed. The use of aerosols is briefly discussed, particularly for free-flying insects.

Specific recommendations are given for flies, mosquitoes, and gnats, cockroaches, fleas, silverfish, ants. J. J. Janzen

791. **Washing machine system for milking machines.** M. P. HANSEN. U. S. Patent 2,717,576. 1 claim. Sept. 13, 1955. Offic. Gaz. U. S. Pat. Office, **698**, 2: 224. 1955.

An arrangement of pipes and valves which permits cleaning, by circulation, of a pipeline type of milking machine. R. Whitaker

792. **Direct washing, flushing, and sterilizing system of stainless steel milk machine pipelines on farms.** B. P. ZIMMER. U. S. Patent 2,714,893. 2 claims. Aug. 9, 1955. Offic. Gaz. U. S. Pat. Office, **697**, 2: 189. 1955.

An arrangement is described for cleaning by circulation with a cleaning solution, a rinsing solution, and a sanitizing agent, all parts of a pipeline-type farm milking system.

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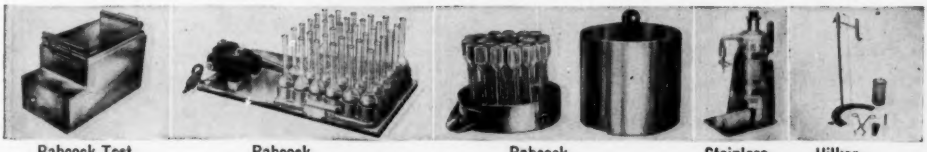

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